For more than two decades “quality” and “quality management systems” have been leading buzzwords in the business world. Numerous consultants have built their careers around these topics, and quality issues in business have been responsible for the development of new organizations and even industries, for instance, the American Society for Quality and Six Sigma consulting.

The notion of quality in business focuses on the savings and additional revenue that organizations can realize if they eliminate errors throughout their operations and produce products and services at the optimal level of quality desired by their customers. Errors can take almost any form—for example, producing the wrong number of parts, sending bank statements to customers who have already closed their accounts or sending an incorrect bill to a client. All
of these errors are very common, and the costs incurred seem minimal. But over time when mistakes are repeated the costs add up to a significant amount, so eliminating errors can result in significant increases to the bottom line of a business.

**WHAT IS QUALITY?**
According to the American Society for Quality, “quality” can be defined in the following ways:

✔ Based on customer’s perceptions of a product/service’s design and how well the design matches the original specifications.

✔ The ability of a product/service to satisfy stated or implied needs.

✔ Achieved by conforming to established requirements within an organization.

**What Is a Quality Management System?**
A quality management system is a management technique used to communicate to employees what is required to produce the desired quality of products and services and to influence employee actions to complete tasks according to the quality specifications.

**Why Is Quality Important?**
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.

**Eight Dimensions of Quality**

There are eight such dimensions of quality. These are:

1. **Performance:**

It involves the various operating characteristics of the product. For a television set, for example, these characteristics will be the quality of the picture, sound and longevity of the picture tube.

2. **Features:**

These are characteristics that are supplemental to the basic operating characteristics. In an automobile, for example, a stereo CD player would be an additional feature.

3. **Reliability:**

Reliability of a product is the degree of dependability and trustworthiness of the benefit of the product for a long period of time.

It addresses the probability that the product will work without interruption or breaking down.
4. **Conformance:**

It is the degree to which the product conforms to pre-established specifications. All quality products are expected to precisely meet the set standards.

5. **Durability:**

It measures the length of time that a product performs before a replacement becomes necessary. The durability of home appliances such as a washing machine can range from 10 to 15 years.

6. **Serviceability:**

Serviceability refers to the promptness, courtesy, proficiency and ease in repair when the product breaks down and is sent for repairs.

7. **Aesthetics:**

Aesthetic aspect of a product is comparatively subjective in nature and refers to its impact on the human senses such as how it looks, feels, sounds, tastes and so on, depending upon the type of product. Automobile companies make sure that in addition to functional quality, the automobiles are also artistically attractive.

8. **Perceived quality:**

An equally important dimension of quality is the perception of the quality of the product in the mind of the consumer. Honda cars, Sony Walkman and Rolex watches are perceived to be high quality items by the consumers.

**Factors affecting QMS.**

When such a standard(s) has (have) been specified, then the quality of the product can be described as “better or worse” or “higher or lower” than the established quality specification(s). In other words, quality is a variable and, when the permissible limits of variability have been stated, quality can be adequately defined for all practical purposes.

1. **Manpower** - Employee working for the product.

2. **Materials** - The quality of raw materials in making a product.

3. **Machine** - Technology used in the product.

4. **Method** - The process used in making the product.

5. **Management** - The organization that working as one.

6. **Environment** - The workplace of the organization and what is the effects in the surroundings.

Dr. Emmanuel Kwesi Arthur
1. Money:

Most important factor affecting the quality of a product is the money involved in the production itself. In the present day of tough and cut throat competition, companies are forced to invest a lot in maintaining the quality of products.

2. Materials:

To turn out a high quality product, the raw materials involved in production process must be of high quality.

3. Management:

Quality control and maintenance programmes should have the support from top management. If the management is quality conscious rather than merely quantity conscious, organisation can maintain adequate quality of products.

4. People:

People employed in production, in designing the products must have knowledge and experience in their respective areas.

5. Market:

Market for the product must exist before quality of the product is emphasized by management. It is useless to talk about the quality when the market for the product is lacking. For example, there is no demand for woolen garments in the hot climates (e.g., Southern part of India).

6. Machines and Methods:

To maintain high standards of quality, companies are investing in new machines and following new procedures and methods these days.

**Standardized Systems**

ISO 9000 is a series of quality management systems (QMS) standards created by the International Organization for Standardization, a federation of 132 national standards bodies. The ISO 9000 QMS standards are not specific to products or services, but apply to the processes that create them. The standards are generic in nature so that they can be used by manufacturing and service industries anywhere in the world.

An organization that would like to have ISO certification needs to meet all the criteria stated in the ISO standards and pass a detailed audit performed by an ISO auditor. In some industries ISO certification has become necessary; for example, some large manufacturers require all suppliers to be ISO certified. While ISO certification is highly respected, if it is not a trend in your specific industry, the additional cost of certification is a deterrent to most managers. It is very possible to
reach the desired quality level within an organization with a well planned quality system and without going through all the additional steps for ISO certification.

QS-9000, released in 1994, is the ISO 9000 derivative for suppliers to the automotive Big Three: Daimler Chrysler, Ford, and General Motors. This quality management system standard contains all of ISO 9001:1994, along with automotive sector-specific, Big Three, and other original equipment manufacturer (OEM) customer specific requirements.

**Control Charts and Their Role in Quality Systems.**

Control charts are the most widely used tool in quality systems. Control charts communicate a lot of information effectively. Figure 14.2 shows a process in which all the outcomes are within the specified limits. The upper control limit (UCL) is .18 and the lower control limit (LCL) is .02, and all the points fall between these two limits. This means the process is in control and operating correctly. If some of the points were to fall outside of the UCL or LCL, it would signal that the process is not in control and action needs to be taken to correct the problem.

We discussed earlier the two different types of errors, (1) systematic and (2) special causes. Systematic errors will show up on a control chart as one or two points outside of the control limits with the rest of the points within the limits. Special causes will show up on a control chart with numerous points outside of the control limits.

The exact use of statistical measures is going to be different for each organization. Some statistical analysis will be very easy to set up and use. For example, the length or weight of a particular part can be measured and analysis can show if the parts are within the required specifications. In service industries the statistical analysis will be more abstract, but is just as valuable. For example, one could survey customers regularly and ask them on a scale of 1 to 10, “How would you rate the service?”

Here are some common traits of statistical measures used in quality systems:

![Control Chart](image)
Statistical Quality Control

After studying this chapter you should be able to

- Describe categories of statistical quality control (SQC).
- Explain the use of descriptive statistics in measuring quality characteristics.
- Identify and describe causes of variation.
- Describe the use of control charts.
- Identify the differences between x-bar, R-, p-, and c-charts.

WHAT IS STATISTICAL QUALITY CONTROL?

Total quality management (TQM) addresses organizational quality from managerial and philosophical viewpoints. TQM focuses on customer-driven quality standards, managerial leadership, continuous improvement, quality built into product and process design, quality identified problems at the source, and quality made everyone’s responsibility. However, talking about solving quality problems is not enough. We need specific tools that can help us make the right quality decisions. These tools come from the area of statistics and are used to help identify quality problems in the production process as well as in the product itself.

Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals. 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. Descriptive statistics are used to describe certain quality characteristics, such as the central tendency and variability of observed data. Although descriptions of certain characteristics are helpful, they are not enough to help us evaluate whether there is a problem with quality. Acceptance sampling can help us do this. Acceptance sampling helps us decide whether desirable quality has been achieved for a batch of products, and whether to accept or reject the items produced. Although this information is helpful in making the quality acceptance decision after the product has been produced, it does not help us identify and catch a quality problem during the production process. For this we need tools in the statistical process control (SPC) category. 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. For this reason, we will devote most of the chapter to this category of tools. The quality control tools we will be learning about do not only measure the value of a quality characteristic. They also help us identify a change or variation in some quality characteristic of the product or process. We will first see what types of variation we can observe when measuring quality. Then we will be able to identify specific tools used for measuring this variation.

Variation in the production process leads to quality defects and lack of product consistency. The Intel Corporation, the world’s largest and most profitable manufacturer of microprocessors, understands this. Therefore, Intel has implemented a program it calls “copy-exactly” at all its manufacturing facilities. The idea is that regardless of whether the chips are made in Arizona, New Mexico, Ireland, or any of its other plants, they are made in exactly the same way. This means using the same equipment, the same exact materials, and workers performing the same tasks in the exact same order. The level of detail to which the “copy-exactly” concept goes is meticulous. For example, when a chipmaking machine was found to be a few feet longer at one facility than another, Intel made them match.

When water quality was found to be different at one facility, Intel instituted a purification system to eliminate any differences. Even when a worker was found polishing equipment in one direction, he was asked to do it in the approved circular pattern. Why such attention to exactness...
of detail? The reason is to minimize all variation. Now let’s look at the different types of variation that exist.

**Acceptance sampling**
The process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results.

**Statistical process control (SPC)**
A statistical tool that 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.

**Sources of Variation: Common and Assignable Causes**

If you look at bottles of a soft drink in a grocery store, you will notice that no two bottles are filled to exactly the same level. Some are filled slightly higher and some slightly lower. Similarly, if you look at blueberry muffins in a bakery, you will notice that some are slightly larger than others and some have more blueberries than others.

These types of differences are completely normal. No two products are exactly alike because of slight differences in materials, workers, machines, tools, and other factors. These are called **common, or random, causes of variation**. Common causes of variation are based on random causes that we cannot identify. These types of variation are unavoidable and are due to slight differences in processing.

An important task in quality control is to find out the range of natural random variation in a process. For example, if the average bottle of a soft drink called Cocoa Fizz contains 16 ounces of liquid, we may determine that the amount of natural variation is between 15.8 and 16.2 ounces. If this were the case, we would monitor the production process to make sure that the amount stays within this range. If production goes out of this range—bottles are found to contain on average 15.6 ounces—this would lead us to believe that there is a problem with the process because the variation is greater than the natural random variation.

Dr. Emmanuel Kwesi Arthur
The second type of variation that can be observed involves variations where the causes can be precisely identified and eliminated. These are called **assignable causes of variation**. Examples of this type of variation are poor quality in raw materials, an employee who needs more training, or a machine in need of repair. In each of these examples the problem can be identified and corrected. Also, if the problem is allowed to persist, it will continue to create a problem in the quality of the product. In the example of the soft drink bottling operation, bottles filled with 15.6 ounces of liquid would signal a problem. The machine may need to be readjusted. This would be an assignable cause of variation. We can assign the variation to a particular cause (machine needs to be readjusted) and we can correct the problem (readjust the machine).

**DESCRIPTIVE STATISTICS**

Descriptive statistics can be helpful in describing certain characteristics of a product and a process. The most important descriptive statistics are measures of central tendency such as the mean, measures of variability such as the standard deviation and range, and measures of the distribution of data. We first review these descriptive statistics and then see how we can measure their changes.

**The Mean**

In the soft drink bottling example, we stated that the average bottle is filled with 16 ounces of liquid. The arithmetic average, or the **mean**, is a statistic that measures the central tendency of a set of data. Knowing the central point of a set of data is highly important. Just think how important that number is when you receive test scores!

To compute the mean we simply sum all the observations and divide by the total number of observations. The equation for computing the mean is

\[
\overline{X} = \frac{\sum_{i=1}^{n} X_i}{N}
\]

where
- \( \overline{X} \) = the mean
- \( X_i \) = observation \( i, i = 1, \ldots, n \)
- \( N \) = number of observations

**The Range and Standard Deviation**

In the bottling example we also stated that the amount of natural variation in the bottling process is between 15.8 and 16.2 ounces. This information provides us with the amount of variability of

Dr. Emmanuel Kwesi Arthur
the data. It tells us how spread out the data is around the mean. There are two measures that can be used to determine the amount of variation in the data. The first measure is the range, which is the difference between the largest and smallest observations. In our example, the range for natural variation is 0.4 ounces.

Another measure of variation is the **standard deviation**. The equation for computing the standard deviation is

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n - 1}}
\]

where
- \( \sigma \) = standard deviation of a sample
- \( \bar{X} \) = the mean
- \( X_i \) = observation \( i, i = 1, \ldots, n \)
- \( n \) = the number of observations in the sample

Small values of the range and standard deviation mean that the observations are closely clustered around the mean. Large values of the range and standard deviation mean that the observations are spread out around the mean. Figure 6-1 illustrates the differences between a small and a large standard deviation for our bottling operation.

You can see that the figure shows two distributions, both with a mean of 16 ounces. However, in the first distribution the standard deviation is large and the data are spread out far around the mean. In the second distribution the standard deviation is small and the data are clustered close to the mean.

![Figure 6-1](image)

Normal distributions with varying and skewed distributions

**FIGURE 6-2** Differences between symmetric standard deviations

**Distribution of Data**

Dr. Emmanuel Kwesi Arthur
A third descriptive statistic used to measure quality characteristics is the shape of the distribution of the observed data. When a distribution is symmetric, there are the same number of observations below and above the mean. This is what we commonly find when only normal variation is present in the data. When a disproportionate number of observations are either above or below the mean, we say that the data has a skewed distribution. Figure 6-2 shows symmetric and skewed distributions for the bottling operation.

**STATISTICAL PROCESS CONTROL METHODS**

Statistical process control methods extend the use of descriptive statistics to monitor the quality of the product and process. As we have learned so far, there are common and assignable causes of variation in the production of every product. Using statistical process control we want to determine the amount of variation that is common or normal.

Then we monitor the production process to make sure production stays within this normal range. That is, we want to make sure the process is in a state of control. The most commonly used tool for monitoring the production process is a control chart. Different types of control charts are used to monitor different aspects of the production process. In this section we will learn how to develop and use control charts.

**Developing Control Charts**

A control chart (also called process chart or quality control chart) is a graph that shows whether a sample of data falls within the common or normal range of variation. A control chart has upper and lower control limits that separate common from assignable causes of variation. The common range of variation is defined by the use of control chart limits. We say that a process is out of control when a plot of data reveals that one or more samples fall outside the control limits. Figure 6-3 shows a control chart for the Cocoa Fizz bottling operation. The x axis represents samples (#1, #2, #3, etc.) taken from the process over time. The y axis represents the quality characteristic that is being monitored (ounces of liquid). The center line (CL) of the control chart is the mean, or average, of the quality characteristic that is being measured. In Figure 6-3 the mean is 16 ounces. The upper control limit (UCL) is the maximum acceptable variation from the
mean for a process that is in a state of control. Similarly, the lower control limit (LCL) is the minimum acceptable variation from the mean for a process that is in a state of control. In our example, the upper and lower control limits are 16.2 and 15.8 ounces, respectively. You can see that if a sample of observations falls outside the control limits we need to look for assignable causes.

**FIGURE 6-3** Quality control chart for Cocoa Fizz

The upper and lower control limits on a control chart are usually set at _3 standard deviations from the mean. If we assume that the data exhibit a normal distribution, these control limits will capture 99.74 percent of the normal variation. Control limits can be set at _2 standard deviations from the mean. In that case, control limits would capture 95.44 percent of the values. Figure 6-4 shows the percentage of values that fall within a particular range of standard deviation.

Looking at Figure 6-4, we can conclude that observations that fall outside the set range represent assignable causes of variation. However, there is a small probability that a value that falls outside the limits is still due to normal variation. This is called Type I error, with the error being the chance of concluding that there are assignable causes of variation when only normal variation exists. Another name for this is alpha risk (_α), where alpha refers to the sum of the probabilities in both tails of the distribution that falls outside the confidence limits. The chance of this happening is given by the percentage or probability represented by the shaded areas of Figure 6-5. For limits of _3 standard deviations from the mean, the probability of a Type I error is .26% (100% _ 99.74%), whereas for limits of _2 standard deviations it is 4.56% (100% _ 95.44%).

Dr. Emmanuel Kwesi Arthur
Types of Control Charts

Control charts are one of the most commonly used tools in statistical process control. They can be used to measure any characteristic of a product, such as the weight of a cereal box, the number of chocolates in a box, or the volume of bottled water. The different characteristics that can be measured by control charts can be divided into two groups: variables and attributes. A control chart for variables is used to monitor characteristics that can be measured and have a continuum of values, such as height, weight, or volume. A soft drink bottling operation is an example of a variable measure, since the amount of liquid in the bottles is measured and can take on a number of different values. Other examples are the weight of a bag of sugar, the temperature of a baking oven, or the diameter of plastic tubing.

A control chart for attributes, on the other hand, is used to monitor characteristics that have discrete values and can be counted. Often they can be evaluated with a simple yes or no decision. Examples include color, taste, or smell. The monitoring of attributes usually takes less time than that of variables because a variable needs to be measured (e.g., the bottle of soft drink contains 15.9 ounces of liquid). An attribute requires only a single decision, such as yes or no, good or bad, acceptable or unacceptable (e.g., the apple is good or rotten, the meat is good or stale, the shoes have a defect or do not have a defect, the light bulb works or it does not work) or counting the number of defects (e.g., the number of broken cookies in the box, the number of dents in the car, the number of barnacles on the bottom of a boat).
Statistical process control is used to monitor many different types of variables and attributes. In the next two sections we look at how to develop control charts for variables and control charts for attributes.

**CONTROL CHARTS FOR VARIABLES**

Control charts for variables monitor characteristics that can be measured and have a continuous scale, such as height, weight, volume, or width. When an item is inspected, the variable being monitored is measured and recorded. For example, if we were producing candles, height might be an important variable. We could take samples of candles and measure their heights. Two of the most commonly used control charts for variables monitor both the central tendency of the data (the mean) and the variability of the data (either the standard deviation or the range). Note that each chart monitors a different type of information. When observed values go outside the control limits, the process is assumed not to be in control. Production is stopped, and employees attempt to identify the cause of the problem and correct it. Next we look at how these charts are developed.

**Mean (x-Bar) Charts**

A mean control chart is often referred to as an *x-bar chart*. It is used to monitor changes in the mean of a process. To construct a mean chart we first need to construct the center line of the chart. To do this we take multiple samples and compute their means. Usually these samples are small, with about four or five observations. Each sample has its own mean. The center line of the chart is then computed as the mean of all _sample means, where _ is the number of samples:

\[
\bar{x} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_n}{n}
\]

To construct the upper and lower control limits of the chart, we use the following formulas:

Upper control limit (UCL) = \( \bar{x} + z\sigma_{\bar{x}} \)

Lower control limit (LCL) = \( \bar{x} - z\sigma_{\bar{x}} \)

where \( \bar{x} \) = the average of the sample means

\( z \) = standard normal variable (2 for 95.44% confidence, 3 for 99.74% confidence)

\( \sigma_{\bar{x}} \) = standard deviation of the distribution of sample means, computed as \( \sigma/\sqrt{n} \)

\( \sigma \) = population (process) standard deviation

\( n \) = sample size (number of observations per sample)

Example 6.1 shows the construction of a mean (x-bar) chart.

**EXAMPLE 6.1 Constructing a Mean (x-Bar) Chart**

A quality control inspector at the Cocoa Fizz soft drink company has taken twenty-five samples with four observations each of the volume of bottles filled. The data and the computed means are shown in the table. If the standard deviation of the bottling operation is 0.14 ounces, use this information to develop control limits of three standard deviations for the bottling operation.
## Observations

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Bottle Volume in Ounces</th>
<th>Average $\bar{x}$</th>
<th>Range $R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.85 16.02 15.83 15.93</td>
<td>15.91</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>16.12 16.00 15.85 16.01</td>
<td>15.99</td>
<td>0.27</td>
</tr>
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<td>3</td>
<td>16.00 15.91 15.94 15.83</td>
<td>15.92</td>
<td>0.17</td>
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<td>4</td>
<td>16.20 15.85 15.74 15.93</td>
<td>15.93</td>
<td>0.46</td>
</tr>
<tr>
<td>5</td>
<td>15.74 15.86 16.21 16.10</td>
<td>15.98</td>
<td>0.47</td>
</tr>
<tr>
<td>6</td>
<td>15.94 16.01 16.14 16.03</td>
<td>16.03</td>
<td>0.20</td>
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<tr>
<td>7</td>
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<td>0.46</td>
</tr>
<tr>
<td>8</td>
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<td>15.93</td>
<td>0.20</td>
</tr>
<tr>
<td>9</td>
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<td>15.96</td>
<td>0.21</td>
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<td>0.30</td>
</tr>
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<td>0.24</td>
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<td>15.91</td>
<td>0.37</td>
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</tr>
<tr>
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<td>16.12 16.08 15.83 15.94</td>
<td>15.99</td>
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<td>15.86</td>
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<td>16.00</td>
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<td>15.90</td>
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</tr>
<tr>
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<td>15.94</td>
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</tr>
<tr>
<td>25</td>
<td>16.08 15.78 15.92 15.98</td>
<td>15.94</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td>398.75</td>
<td>7.17</td>
<td></td>
</tr>
</tbody>
</table>
Solution
The center line of the control data is the average of the samples:

\[ \overline{x} = \frac{398.75}{25} \]

\[ \overline{x} = 15.95 \]

The control limits are

Upper control limit (UCL) = \( \overline{x} + z \sigma_{\overline{x}} = 15.95 + 3 \left( \frac{.14}{\sqrt{4}} \right) = 16.16 \)

Lower control limit (LCL) = \( \overline{x} - z \sigma_{\overline{x}} = 15.95 - 3 \left( \frac{.14}{\sqrt{4}} \right) = 15.74 \)

The resulting control chart is:

Another way to construct the control limits is to use the sample range as an estimate of the variability of the process. Remember that the range is simply the difference between the largest and smallest values in the sample. The spread of the range can tell us about the variability of the data. In this case control limits would be constructed as follows:

Upper control limit (UCL) = \( \overline{x} + A_2 \overline{R} \)

Lower control limit (LCL) = \( \overline{x} - A_2 \overline{R} \)

where \( \overline{x} \) = average of the sample means
\( \overline{R} \) = average range of the samples
\( A_2 \) = factor obtained from Table 6-1.
Notice that $A_2$ is a factor that includes three standard deviations of ranges and is dependent on the sample size being considered.

**EXAMPLE 6.2 Constructing a Mean (x-Bar) Chart from the Sample Range**

A quality control inspector at Cocoa Fizz is using the data from Example 6.1 to develop control limits. If the average range ($\bar{R}$) for the twenty-five samples is .29 ounces (computed as $\frac{\sum R}{25}$) and the average mean ($\bar{x}$) of the observations is 15.95 ounces, develop three-sigma control limits for the bottling operation.

**Solution**

\[
\bar{x} = 15.95 \text{ ounces} \quad \bar{R} = .29
\]

The value of $A_2$ is obtained from Table 6.1. For $n = 4$, $A_2 = .73$. This leads to the following limits:

- The center of the control chart = CL = 15.95 ounces
- UCL = $\bar{x} + A_2 \bar{R} = 15.95 + (.73)(.29) = 16.16$
- LCL = $\bar{x} - A_2 \bar{R} = 15.95 - (.73)(.29) = 15.74$

**TABLE 6-1**

Factors for three-sigma control limits of and R-charts

*Source: Factors adapted from the *ASTM Manual on Quality Control of Materials*.*
**INSPECTION**

Inspection is the most common method of attaining standardisation, uniformity and quality of workmanship. It is the cost art of controlling the product quality after comparison with the established standards and specifications. It is the function of quality control. If the said item does not fall within the zone of acceptability it will be rejected and corrective measure will be applied to see that the items in future conform to specified standards.

Inspection is an indispensable tool of modern manufacturing process. It helps to control quality, reduces manufacturing costs, eliminate scrap losses and assignable causes of defective work.

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Objectives of Inspection

(1) To collect information regarding the performance of the product with established standards for the use of engineering production, purchasing and quality control etc.
(2) To sort out poor quality of manufactured product and thus to maintain standards.
(3) To establish and increase the reputation by protecting customers from receiving poor quality products.
(4) Detect source of weakness and failure in the finished products and thus check the work of designer.

Purpose of Inspection

(1) To distinguish good lots from bad lots
(2) To distinguish good pieces from bad pieces.
(3) To determine if the process is changing.
(4) To determine if the process is approaching the specification limits.
(5) To rate quality of product.
(6) To rate accuracy of inspectors.
(7) To measure the precision of the measuring instrument.
(8) To secure products – design information.
(9) To measure process capability.

Stages of Inspection

(1) Inspection of incoming material
(2) Inspection of production process
(3) Inspection of finished goods.

2 TOTAL QUALITY MANAGEMENT

(1) Inspection of incoming materials. It is also called receiving inspection. It consists of inspecting and checking of all the purchased raw materials and parts that are supplied before they are taken on to stock or used in actual manufacturing. Inspection may take place either at supplier’s end or at manufacturer’s gate. If the incoming materials are large in quantity and
involve huge transportation cost it is economical to inspect them at the place of vendor or supplier.

(2) **Inspection of production process.** The work of inspection is done while the production process is simultaneously going on. Inspection is done at various work centres of men and machines and at the critical production points. This had the advantage of preventing wastage of time and money on defective units and preventing delays in assembly.

(3) **Inspection of finished goods.** This is the last stage when finished goods are inspected and carried out before marketing to see that poor quality product may be either rejected or sold at reduced price.

**Inspection Procedures**

There are three ways of doing inspection. They are Floor inspection, Centralised inspection and Combined inspection.

**Floor Inspection**

It suggests the checking of materials in process at the machine or in the production time by patrolling inspectors. These inspectors moves from machine to machine and from one to the other work centres. Inspectors have to be highly skilled. This method of inspection minimise the material handling, does not disrupt the line layout of machinery and quickly locate the defect and readily offers field and correction.

**Advantages**

(1) Encourage co-operation of inspector and foreman.

(2) Random checking may be more successful than batch checking.

(3) Does not delay in production.

(4) Saves time and expense of having to more batches of work for inspection.

(5) Inspectors may see and be able to report on reason of faculty work.

**Disadvantages**

(1) Difficult in inspection due to vibration.

(2) Possibility of biased inspection because of worker.

(3) Pressure on inspector.

(4) High cost of inspection because of numerous sets of inspections and skilled inspectors.

**Suitability**

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(1) Heavy products are produced.
(2) Different work centres are integrated in continuous line layout.

Centralised Inspection

Materials in process may be inspected and checked at centralised inspection centre which are located at one or more places in the manufacturing industry.

QUALITY AND QUALITY CONTROL

Advantages

(1) Better quality checkup.
(2) Closed supervision.
(3) Absence of workers pressure.
(4) Orderly production flow and low inspection cost.

Disadvantages

(1) More material handling.
(2) Delays of inspection room causes wastage of time.
(3) Work of production control increases.
(4) Due to non-detection of machining errors in time, there may be more spoilage of work.

Suitability

(1) Incoming materials inspection.
(2) Finished product inspection.
(3) Departmental inspection.
(4) High precision products of delicate products.
(5) Small and less expensive products.

Combined Inspection

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Combination of two methods whatever may be the method of inspection, whether floor or central. The main objective is to locate and prevent defect which may not repeat itself in subsequent operation to see whether any corrective measure is required and finally to maintained quality economically.

Methods of Inspection

There are two methods of inspection. They are 100% inspection and Sampling inspection.

100% Inspection

This type will involve careful inspection in detail of quality at each strategic point or stage of manufacture where the test involved is non-destructive and every piece is separately inspected. It requires more number of inspectors and hence it is a costly method.

There is no sampling error. This is subjected to inspection error arising out of fatigue, negligence, difficulty of supervision etc. Hence complete accuracy of influence is seldomly attained. It is suitable only when a small number of pieces are there or a very high degree of quality is required. Example: Jet engines, Aircraft, Medical and Scientific equipment.

Sampling Inspection

In this method randomly selected samples are inspected. Samples taken from different batches of products are representatives. If the sample prove defective. The entire concerned is to be rejected or recovered. Sampling inspection is cheaper and quicker. It requires less number of Inspectors. Its subjected to sampling errors but the magnitude of

TOTAL QUALITY MANAGEMENT

sampling error can be estimated. In the case of destructive test, random or sampling inspection is desirable. This type of inspection governs wide currency due to the introduction of automatic machines or equipments which are less susceptible to chance variable and hence require less inspection, suitable for inspection of products which have less precision importance and are less costly.

Example: Electrical bulbs, radio bulbs, washing machine etc.

Destructive tests conducted for the products whose endurance or ultimate strength properties are required.

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Example: Flexible strength, resistance capacity, compressibility etc.

Drawbacks of Inspection

(1) Inspection adds to the cost of the product but not for its value.

(2) It is partially subjective, often the inspector has to judge whether a product passes or not.

Example: Inspector discovering a slight burnish on a surface must decide whether it is bad enough to justify rejection even with micrometers a tight or loose fit change measurement by say 0.0006 inches. The inspectors design is important as he enforces quality standards.

(3) Fatigue and Monotony may affect any inspection judgement.

(4) Inspection merely separates good and bad items. It is no way to prevent the production of bad items.

Quality

Different meaning could be attached to the word Quality under different circumstances. The word Quality does not mean the Quality of manufactured product only. It may refer to the Quality of the process (i.e., men, material, machines) and even that of management. Where the quality of manufactured product referred as or defined as “Quality of product as the degree in which it fulfills the requirement of the customer. It is not absolute but it judged or realised by comparing it with some standards”.

It is usually determined by some characteristics namely design, size, material, chemical composition, mechanical functioning workmanship, finish and other properties. In the final analysis the Quality standards for the products are established by the customer.

Example: Gear used in sugarcane extracting machine through not of the same material and without possessing good finish, tolerance and accuracy as that of gear used in the hand stock of a teeth may be considered of good quality if it work satisfactory in the juice extracting machine.

Quality begins with the design of a product in accordance with the customer specification further it involves the established measurement standards, the use of proper material,
selection of suitable manufacturing process and the necessary tooling to manufacture the product, the performance of the necessary manufacturing operations and the inspection of the product to check the manufacturing operations and the inspection of the product to check on performance with the specifications. Quality characteristics can be classified as follows:

1. Quality of design
2. Quality of conformance with specifications

QUALITY AND QUALITY CONTROL 5

Control

The process through which the standards are established and met with standards is called control. This process consists of observing our activity performance, comparing the performance with some standard and then taking action if the observed performance is significantly different from the standards.

The control process involves a universal sequence of steps as follows:

1. Choose the control subject.
2. Choose a unit of measure.
3. Set a standard value *i.e.*, specify the quality characteristics
4. Choose a sensing device which can measure.
5. Measure actual performance.
6. Interpret the difference between actual and standard.
7. Taking action, if any, on the difference.

Quality Control

Quality control can be defined as that Industrial Management technique by means of which product of uniform acceptable quality is manufactured.

Factors Affecting Quality

1. Men, Materials and Machines
2. Manufacturing conditions
3. Market research in demand of purchases
(4) Money in capability to invest
(5) Management policy for quality level
(6) Production methods and product design
(7) Packing and transportation
(8) After sales service

**Objectives of Quality Control**

(1) To decide about the standard of Quality of a product that is easily acceptable to the customer.
(2) To check the variation during manufacturing.
(3) To prevent the poor quality products reaching to customer.

**Statistical Quality Control (SQC)**

A Quality control system performs inspection, testing and analysis to conclude whether the quality of each product is as per laid quality standard or not. It’s called “Statistical Quality Control” when statistical techniques are employed to control quality or to solve quality control problem. SQC makes inspection more reliable and at the same time less costly. It controls the quality levels of the outgoing products.

SQC should be viewed as a kit of tools which may influence related to the function of specification, production or inspection.

6 TOTAL QUALITY MANAGEMENT

A successful SQC programme is expected to yield the following results:

(1) Improvement of quality.
(2) Reduction of scrap and rework.
(3) Efficient use of men and machines.
(4) Economy in use of materials.
(5) Removing production bottle-necks.
(6) Decreased inspection costs.
(7) Reduction in cost/unit.
(8) Scientific evaluation of tolerance.
(9) Scientific evaluation of quality and production.
(10) Quality consciousness at all levels.
(11) Reduction in customer complaints.

**Tools of SQC**

The principle tools of SQC are as follows:

1. Frequency distribution.
2. Control charts for measurement and attribute data.
3. Acceptance sampling techniques.
4. Regression and correlation analysis.
5. Tests of significance.
6. Design of experiments.

**QUALITY CHARACTERISTICS**

**Quality of Design**

Quality design is a technical term. It can be regarded as a composite of 3 separate terms or steps in a common progression of activities.

(i) Identification of what constitutes fitness for use to the user (Quality of market research).

(ii) Choice of concept of product or service to be responsible to the identified needs of the user (Quality of concept).

(iii) Translation of the chosen product concept into a detailed set of specifications which is faithfully executed, will then meet the user’s need (Quality of specification).

The total progression composed of these three activities is called “Quality of Design” and it may be said to consist of Quality of market research: Quality of concept and Quality of specification.

**Example:** All automobiles provide the user with the service of transportation. The various models differ as to size, comfort, appearance, performance, economy, status conferred etc. These differences are in turn the results of intended or designed differences in the size, styling, materials, tolerances, test programs etc. Higher quality of design can be attained only at an increase in costs.

**QUALITY AND QUALITY CONTROL**

**Quality of Comformance**

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The design must reflect the needs of fitness for use, and the products must also confirm to the design. The extent to which the product does confirm to the design is called “Quality of conformance”. This extent of conformance is determined by variables as:

(i) Choice of process i.e., whether they are able to hold the tolerances.

(ii) Training of the supervision and the work force.

(iii) Degree of adherence to the program of inspect, test, audit etc. motivation for quality.

Higher quality of conformance can be attained with an accompanying reduction in cost.

Example: Two scooters both are produced at the same level of time but one may be 100% according to the drawing and specification of the same design; the second scooter may be 90% according to the drawing and specification and probably a few dimensions may be different from those of drawing. Therefore, quality of conformance of 1st scooter is better than the 2nd scooter even though both are of same design.

Quality Costs

Quality costs are the incurring in introducing quality and benefits. This is done by identifying and defining the following categories of costs which are associated with making, finding, repairing or avoiding (preventing) defects.

```
Quality Costs

Direct cost  Indirect cost

Failure costs  Preventive costs  Appraisal costs

Internal       External
```

Fig. 1.1. Hierarchy of quality cost or Breakdown of quality cost.

(A) Failure costs

Internal failure costs. These are costs which would disappear if no defects exit in the product prior to shipment to the customer. They include.

Scrap: The net loss in labour and material resulting from defectives which cannot economically be repaired or used.

Rework: The cost of correcting defectives to make them fit for use.

Retest: The cost of inspection and retest of products that have undergone rework or other revision.

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**Down time:** The cost of idle facilities resulting from defects. (Example: Aircraft idle due to unreliability, printing press down due to paper break).

**Yield losses:** The cost of process yield lower that might be attainable by improved controls. Includes “overfill” of containers (going to customers) due to variability in filling and measuring equipment.

**TOTAL QUALITY MANAGEMENT**

**External failure costs.** These costs would also disappear if there were no defects.

They are distinguished from the internal failure costs by the fact that the defects are found at the shipment to the customer. They include:

**Complaint adjustment:** All costs of investigation and adjustment of justified complaints attributable to defective product or installation.

**Returned material:** All costs associated with receipts and returned from the field.

**Warranty charges:** All costs involved in service to customers under warranty contracts.

**Allowances:** Costs of concessions made to customers due to substandard products being accepted by the customer as is include loss in income due to down grading products for sale as seconds.

**(B) Appraisal Costs**

These are costs incurred to discover the conditions of the products, mainly during the “first come through” costs include.

**Incoming material inspection:** The cost of determining the quality of vendor made products, whether by inspection on receipt or at source or by surveillance method.

**Inspection and test:** The cost of checking the conformance of the product throughout its progression, in the factory, including final acceptance and check of packing and shipping includes life, environmental and reliability tests. Also includes testing done at customer’s premises prior to giving up the product to the customer.

**Maintaining accuracy of test equipment:** Includes the cost of operating the system that keeps the measuring instruments and equipment in calibration.

**Materials and services consumed:** Includes costs of product consumed through destructive tests, materials consumed and services where significant.

**Evaluation of stock:** Include the costs of testing products in field storage or in stock to evaluate degradation.
(C) Prevention Costs

These costs are incurred to keep future and appraisal costs at a minimum. It includes:

**Quality Planning:** This includes the broad array of activities which collectively create quality plan, the inspection plan, reliability plan, data system and numerac specialised plans. It includes also preparation of the manuals and procedures needed to communicate these plans to all concerned.

**New Product review:** Includes preparation of bid proposals evaluation of new design, preparation of test and experiment programs and other quality activities associated with the launching of new designs.

**Training:** The costs of preparing training programs for attaining and improving quality performance includes the cost of conducting formal training programs as well.

**Process control:** Includes that part of process control which is conducted to achieve fitness for use as distinguished from achieving productivity, safety *etc.*

**QUALITY AND QUALITY CONTROL**

**Quality data acquisition and analysis:** This is the work of running the quality of data systems to acquire continuing data on quality performance. It includes analysis of these data to identify the quality troubles, to sound alarms *etc.*

**Quality reporting:** Includes the work of summaring and publishing quality information to the middle and upper management.

**Improvement Projects:** Includes the work of structuring and carrying out programs for breakthrough to new levels of performance *i.e.,* defective prevention programs, motivation programs *etc.*

**Total Quality Control**

Total Quality Control defined as an effective system for integrating the quality development, quality maintainance and quality improvement efforts of the various groups in an organisation so as to enable production and service at the most economical level which allow for full customer satisfaction.

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It may be classified as a “Management Tool” for many industries outstanding improvement in product quality design and reduction in operating costs and losses.

Product quality is defined as “The composite product of engineering and manufacture that determine the degree to which the product in use will meet the expectations of the customer”.

“Control” represents a tool with four steps:

- Setting up of quality standards.
- Appraising conformance to these standards
- Acting when these standards are exceeded.
- Planning for improvements in these standards.

Quality control emerges as a based function based on the collection analysis and interpretations of data on all aspects of the enterprise.

Total quality control is an aid for good engineering designs, good manufacturing methods and conscious inspection activity that have always been required for the production of high quality articles.

Quality of any product is effected at many stages of the industrial cycle:

**Marketing:** Evaluates the level of Quality which customers want for which they are willing to pay.

**Engineering:** Reduces this marketing evaluations to exact specification.

**Purchasing:** Chooses, contracts with and retains vendors for parts and materials.

**Manufacturing Engineering:** Select the jigs, tools and processes for production.

**Manufacturing Supervision and shop operators:** Exert a major quality influence during parts making, sub assembly and final assembly.

**Mechanical Inspection and function Test:** Check conformance to specifications.

**Shipping:** Influences the calibre of packaging and transportation.

**Installation:** Helps ensure proper operations by installing the product according to proper instructions and maintaining it through product service.

**TOTAL QUALITY MANAGEMENT**

In other words, the determination of both quality and quality costs actually takes place throughout the entire industrial cycle.

Quality control is responsible for quality assurance at optimum quality costs. The benefits resulting from Total Quality Control programmes are:

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• Improvements in product quality and design
• Reduction in operating costs and losses
• Reduction in production line bottle necks
• Improvement in employee morale
• Improved inspection methods
• Setting time standards for labour
• Definite schedule for preventive maintainance
• Availability of purposeful data for use in co-advertising

Furnishing of actual basis for cost accounting for standard and for scrap, rework and inspection.

Quality Assurance vs Quality Control

Quality Assurance is process oriented and focuses on defect prevention, while quality control is product oriented and focuses on defect identification.

Differences between Quality Assurance and Quality Control

Definitions of QA and QC

• **Quality Assurance (QA)** refers to the process used to create the deliverables, and can be performed by a manager, client, or even a third-party reviewer. Examples of quality assurance include process checklists, project audits and methodology and standards development.

• **Quality Control (QC)** refers to quality related activities associated with the creation of project deliverables. Quality control is used to verify that deliverables are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, deliverable peer reviews and the testing process.

• Quality control is about adherence to requirements. Quality assurance is generic and does not concern the specific requirements of the product being developed.

• Quality assurance activities are determined before production work begins and these activities are performed while the product is being developed. In contrast, Quality control activities are performed after the product is developed.

The difference is that QA is process oriented and QC is product oriented. Testing, therefore is product oriented and thus is in the QC domain. Testing for quality isn't assuring quality, it's controlling it.

• **Quality Assurance** makes sure you are doing the right things, the right way.
• **Quality Control** makes sure the results of what you've done are what you expected.

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<table>
<thead>
<tr>
<th><strong>Quality Assurance</strong></th>
<th><strong>Quality Control</strong></th>
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<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>QA is a set of activities for ensuring quality in the processes by which products are developed.</td>
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<tr>
<td></td>
<td>QC is a set of activities for ensuring quality in products. The activities focus on identifying defects in the actual products produced.</td>
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<tr>
<td><strong>Focus on</strong></td>
<td>QA aims to prevent defects with a focus on the process used to make the product. It is a proactive quality process.</td>
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<td></td>
<td>QC aims to identify (and correct) defects in the finished product. Quality control, therefore, is a reactive process.</td>
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<tr>
<td><strong>Goal</strong></td>
<td>The goal of QA is to improve development and test processes so that defects do not arise when the product is being developed.</td>
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<td></td>
<td>The goal of QC is to identify defects after a product is developed and before it's released.</td>
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<tr>
<td><strong>How</strong></td>
<td>Establish a good quality management system and the assessment of its adequacy. Periodic conformance audits of the operations of the system.</td>
</tr>
<tr>
<td></td>
<td>Finding &amp; eliminating sources of quality problems through tools &amp; equipment so that customer's requirements are continually met.</td>
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<tr>
<td><strong>What</strong></td>
<td>Prevention of quality problems through planned and systematic activities including documentation.</td>
</tr>
<tr>
<td></td>
<td>The activities or techniques used to achieve and maintain the product quality, process and service.</td>
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<tr>
<td><strong>Responsibility</strong></td>
<td>Everyone on the team involved in developing the product is responsible for quality assurance.</td>
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<tr>
<td></td>
<td>Quality control is usually the responsibility of a specific team that tests the product for defects.</td>
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<tr>
<td><strong>Example</strong></td>
<td>Verification is an example of QA</td>
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<td>Validation/Software Testing is an example of QC</td>
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<tr>
<td><strong>Statistical Techniques</strong></td>
<td>Statistical Tools &amp; Techniques can be applied in both QA &amp; QC. When they are applied to processes (process inputs &amp;</td>
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<td>When statistical tools &amp; techniques are applied to finished products (process</td>
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<tr>
<td>Quality Assurance</td>
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<td>operational parameters), they are called Statistical Process Control (SPC); &amp; it becomes the part of QA.</td>
<td>outputs), they are called as Statistical Quality Control (SQC) &amp; comes under QC.</td>
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<tr>
<td><strong>As a tool</strong> QA is a managerial tool</td>
<td>QC is a corrective tool</td>
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<tr>
<td><strong>Orientation</strong> QA is process oriented</td>
<td>QC is product oriented</td>
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