Applying Statistical Process Control to the Production Process of a Signal Cable Products Manufacturer

by

Mr. Thanakorn Sirapanivong

A Final Report of the Three-Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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Academic Year	November 2006

The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

The objective of this study project is to apply the Statistical Process Control (SPC) Methodology to the production process of the a factory. SPC is one of the important tools of the quality control system. It is used to monitor the characteristics of the process and analyze to see whether the process is in or out of control, This project begins with the observation of the cable production processes Since there are many processes in the production line, it has to decide which process should be selected to apply SPC to monitor its characteristics. And the decision of data collecting (how to collect the sample and how many samples should be collected to construct the control chart) should be designed. The control chart that will be used is the np-chart, which is the control chart for attributes. The np-chart is used to determine the number of nonconforming items of the sampled product.

This project study is also a pilot project for the other processes in this line of production. It should be useful to improve the quality of the products when it is implemented in the future.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this project would not have been possible. I would like to express appreciation to my advisor, Dr.Chamnong Jungthirapanich for his assistance, guidance, and comment that led me through to the project completion.

I would like to thank all the staff of FUJIKURA THAILAND Co., Ltd. who kindly helped me gather the information for doing this project.

Special appreciation goes to my family for their fervent and continuous encouragement. Above all, I am forever grateful to my parents whose willingness to invest in my future has enabled me to achieve my educational goal.

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I. INTRODUCTION

1.1 Overview of the Project

Statistical Process Control (SPC) is one of the most useful tools the Quality Control systems. SPC applies the statistical technique to investigate the operation processes if they are in the controlled limit.

The objective of this project is to study the application of Statistical Process Control (SPC) to the production line of cable for FUJIKURA THAILAND This company is located in Navanakorn estate.

It produces the cable products which are:

1) Signal cables and

2) Power cords

This project will concentrate only on Signal cable products, which is the core business of the company. This is the first time that SPC is being used in the production process. At present, they just manually inspect the defective products. Applying SPC should provide them more information about the process that they are working with such as keeping track to see if the process is in or out of control, and it may also point the "bad events" of the production process. The briefly the following description of all Production Processes in making Signal cable is discussed in the following chapters.

1.2 Background of the Study Industrial

This section will discuss the process of the Signal cable production, and the type of the defects found in the production processes. This is the basis to understand the criteria that will be used in studying this project. 1.6.1 Production Process

The production processes to make Signal cable are divided into six main processes, which is shown in Figure 1.2.

1. Drawing
2. Bunching
3. Insulation
4. Stranding
5. Shielding
6. Jacketing

Step 1 Drawing Process

In the first step, Big Diameter Copper Rod are delivered from DDK THAILAND (IN FUJIKURA GROUP) to support this material and this size of copper is very big so Fujikura Thailand draws this copper rod through M/C drawing G class and F class to make It smaller so that Fujikura can use this copper.

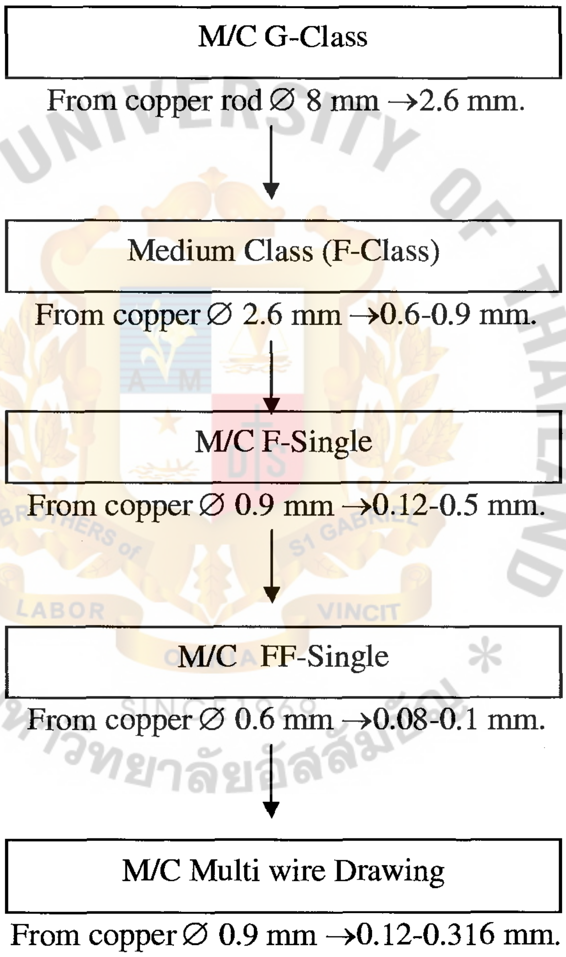


Figure 1.1

Step 2 Bunching

In this process Fujikura will use copper for Bunching them in a group for each signal cable and divide to a group type such as 7/22 means 7 wires and each diameter to be equal to 0.22 mm.

Step 3 Insulation

The process will use a copper from Bunching product and use material such as PVC or PU or other materials depend on different product types.

Step 4 Stranding

Use many core wires to strand with other component such as fillers,

paper tapes. Shielding, which has two directions (clockwise and other clockwise) depending on specifications and applications.

Step 5 Shielding

For this process we will use core wire and made from copper to protect inside and outside signal cables not to be interfere and can separate it from format to

Braiding shield

Spiral shield

Aluminum shield

Step 6 Jacketing

Bring core from previous process and use plastic materialท and use machine extruders to wrap core and writing specification on finished cables.

1.3 Purposes of Study

The objectives of the study are:

1) To apply SPC technique to the cable production line to detect the nonconformity of the products.

2) To replace the manual inspection which has no record of defective data to see the trends of the process or to point the problems to find its cause.

3) To be the guideline for other processes in the production line for the future development.

1.4 Statement of the Problem

This project is the study of inspection (quality control) process of the Signal cable production. The present system is uses manual inspection. The new system, which will using the Statistical Process Control (SPC) technique should be used to replace the existing system. The hypothesis of this study is "To see whether the production process have any problems". This study attempts to answer these statements of problems:

1) Is the production process is in control?

2) What are the causes of the nonconformance products?

3) How appropriate to apply the SPC technique to this production process?

4) What should be done further in quality control system?

1.5 Scope of the Study

This project study is concentrating on the nonconforming products in the production processes, as follows:

1) Concentrate only on the Signal cable product.
2) Select one of the Signal cable models to study its characteristics. This product should be a lot size much enough to analyze by using SPC control chart in order to monitor the process characteristics.
3) Concentrate only on the problem defect Processes in the production process.
4) Using the Pareto Chart, Attributes control chart, and Cause-and-effect diagram to analyze the result of the gathered data.

1.6 Delimitation

This study is to apply SPC to the production processes. A lot of data of the defective products should be collected. However, in the existing system, there are not any recorded data that is needed for this study, so we have to ask the staff of the manufacturer to collect these data. At the first time a 100% inspection is desired, but in practice it takes a lot of time and manpower. So collecting the data by using sampling is used instead, which is more feasible, but may result in a little bit of deviation. The limit of time for this project may cause the characteristics of the control chart to not be accurate.

In addition, there is another factor that causes the result of the study to be varied; it is the model of the Signal cable that always changes. Because the difference of the signal cable model can cause the different result in the defective product. So when constructing the control chart we have to separate the chart for each model.

II. LITERATURE REVIEW

2.1 Overview of Quality Control

Quality management is one of the most important systems to make an organization survive in the business. The definition of quality as adopted by the American Society for Quality: "The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs". There are many tools that helpful in the Total Quality Management effort, which are

2.1.1 Check Sheets

A check sheet is any kind of a form that, is designed for recording data. In many cases, the recording is done so the patterns are easily seen while the data are being taken. Check sheets help analysts find the facts or patterns that may aid subsequent analysis. An example might be a drawing that shows a tally of the areas where defects are occurring or a check sheet showing the type of customer complaints.

Check sheets are some of the most common tools used for collecting data. They allow the data to be collected in an easy, systematic, and organized manner. Also, data collected using check sheets can be used as input data for other quality tools such as Pareto diagrams. There are four main types of check sheets used for data collection (custom check sheets can also be designed to fit specific needs).

1. Defective Item Check Sheet:

This type of check sheet is used to identify what types of problems or defects are occurring in the process. Usually these check sheets will have a list of the defects or problems that may occur in the process. When each sample is taken, a mark is placed in the appropriate column whenever a defect or a problem has been identified. The type of data used in the defective item check sheets is countable data. Table 1 below shows an example of a defective item check sheet for the wave solder manufacturing process.

Table 1.1 Wave Solder Defect Count.

Defect Type	**Insufficient Solder**	**Cold Solder**	**Solder Bridge**	**Blow Holes**	**Excessive Solder**
Frequency	Xxxxxxx	xx	xxx	xxxxxxxxxxxxxx	xx
Total	7	2	3	14	2

Defective Location Check Sheet:

These type of check sheets are used to identify the location of the defect on the product. They are used when the external appearance of the product is important. Usually this type of check sheet consists of a picture of the product. On this picture, marks can be made to indicate were defects are occurring on the surface of the product.

Defective Cause Check Sheet:

This type of check sheet tries to identify causes of a problem or a defect. More than one variable is monitored when collecting data for this type of check sheets. For example, we could be collecting data about the type of machine, operator, date, and time on the same check sheet. Table 2 below is an example of this type of check sheets. As we can see most of the errors are occurring at machine 2 and at the afternoon shift. This could suggest that machine 2 has problems when it is run in the afternoon shift.

Table 1.2 Defect cause check sheet.

		Machine 1	Machine 2
Operator A	Morning	X	X
	Afternoon	XX	XXXXXX
Operator B	Morning	X	XX
	Afternoon	XX	XXXXXXXXX

X= Number of times the supervisor is called per day.

4. Checkup Confirmation Check Sheet:

This type of check sheet is used to ensure that proper procedures are being followed. These check sheets usually will have a list of tasks that need to be accomplished before the action can be taken. Examples of checkup confirmation check sheets are final inspection, machine maintenance, operation checks, and service performance check sheets.

Conclusion:

Check sheets are helpful tools for proper data collection. They are easy to use and allow the user to collect data in a systematic and organized manner. Many types of check sheets are available. The most common are the defective items, defective location, defective causes, and checkup confirmation check sheets.

Scatter Diagrams

Scatter diagrams show the relationship between two measurements. An example is the positive relationship between length of a service call and the number of trips the repairperson makes back to the truck for parts. Another example might be a plot of productivity and absenteeism. If the two items are closely related, the data points will form a tight band. If a random pattern results, the items are unrelated.

The method used to identify the exact nature of the relationship between two variables.

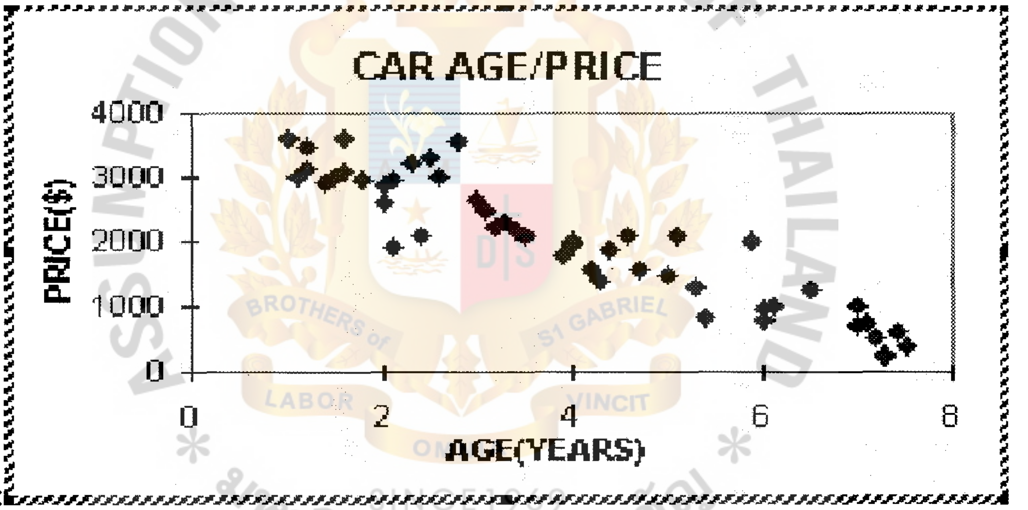


Figure 2.1 Construction of scatter diagram

2.1.3 Cause-and-Effect Diagrams

The cause & effect diagram is the brainchild of Kaoru Ishikawa, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management. The cause and effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output). Causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events. This can help you search for root causes, identify areas where there may be problems, and compare the relative importance of different causes.

Causes in a cause & effect diagram are frequently arranged into four major categories. While these categories can be anything, you will often see:

- manpower, methods, materials, and machinery (recommended for manufacturing)
- equipment, policies, procedures, and people (recommended for administration and service).

These guidelines can be helpful but should not be used if they limit the diagram or are inappropriate. The categories you use should suit your needs. At SkyMark, we often create the branches of the cause and effect tree from the titles of the affinity sets in a preceding affinity diagram.

The C&E diagram is also known as the fishbone diagram because it was drawn to resemble the skeleton of a fish, with the main causal categories drawn as "bones" attached to the spine of the fish, as shown below.

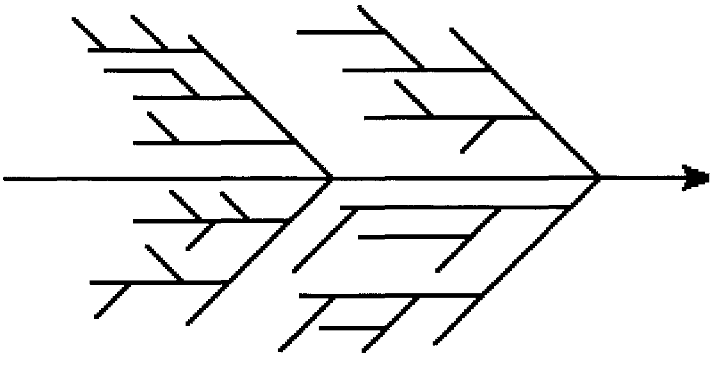


Figure 2.2 Construction of scatter diagram

Cause & effect diagrams can also be drawn as tree diagrams, resembling a tree turned on its side. From a single outcome or trunk, branches extend that represent major categories of inputs or causes that create that single outcome. These large branches then lead to smaller and smaller branches of causes all the way down to twigs at the ends. The tree structure has an advantage over the fishbone-style diagram. As a fishbone diagram becomes more and more complex, it becomes difficult to find and compare items that are the same distance from the effect because they are dispersed over the diagram. With the tree structure, all items on the same causal level are aligned vertically.

2.1.4 Pareto Charts

Pareto Charts

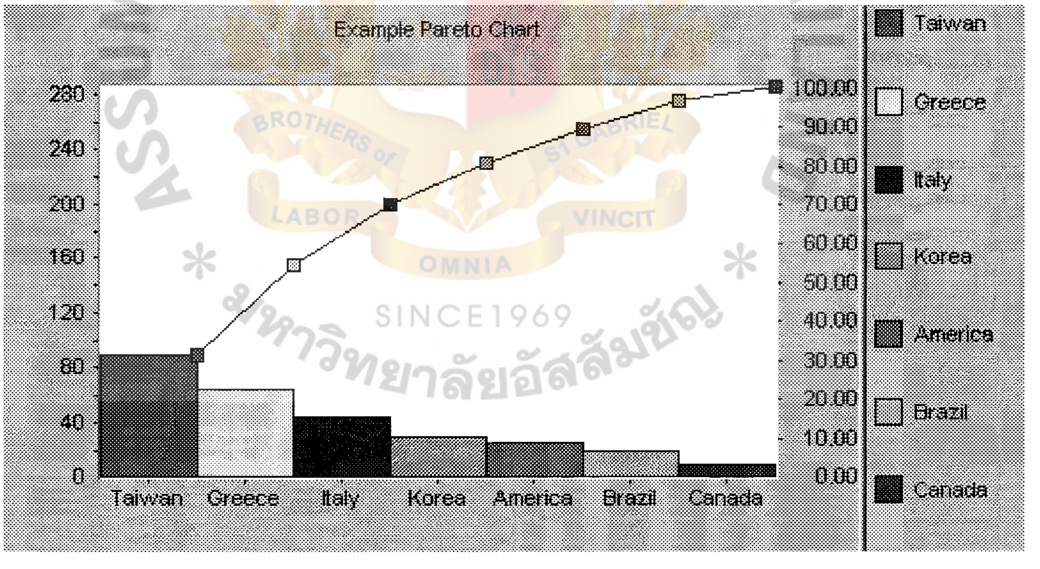


Figure 2.3 Pareto diagram

Vilfredo Pareto, a turn-of-the-century Italian economist, studied the distributions of wealth in different countries, concluding that a fairly consistent minority – about 20% – of people controlled the large majority – about 80% – of a society's wealth. This same distribution has been observed in other areas and has been termed the Pareto effect.

The Pareto effect even operates in quality improvement: 80% of problems usually stem from 20% of the causes. Pareto charts are used to display the Pareto principle in action, arranging data so that the few vital factors that are causing most of the problems reveal themselves. Concentrating improvement efforts on these few will have a greater impact and be more cost-effective than undirected efforts.

Things to look for:

In most cases, two or three categories will tower above the others. These few categories which account for the bulk of the problem will be the high-impact points on which to focus. If in doubt, follow these guidelines:

Look for a break point in the cumulative percentage line. This point occurs where the slope of the line begins to flatten out. The factors under the steepest part of the curve are the most important.

If there is not a fairly clear change in the slope of the line, look for the factors that make up at least 60% of the problem. You can always improve these few, redo the Pareto analysis, and discover the factors that have risen to the top now that the biggest ones have been improved.

If the bars are all similar sizes or more than half of the categories are needed to make up the needed 60%, try a different breakdown of categories that might be more appropriate. Often, one Pareto chart will lead to another:

- before and after charts
- charts that break down the most important factors discovered in an earlier chart

- charts that use different scales, such as number of complaints and the cost to respond, with the same categories.

Pareto chart statistics:

For the Pareto chart, the following overall statistics are calculated:

Mean: the average of all the values in the series, i.e. the average bar height.

Sum: the sum of all the values in the series.

2.1.5 Flowcharts

Flowcharting

Flowcharts are maps or graphical representations of a process. Steps in a process are shown with symbolic shapes, and the flow of the process is indicated with arrows connecting the symbols. Computer programmers popularized flowcharts in the 1960's, using them to map the logic of programs. In quality improvement work, flowcharts are particularly useful for displaying how a process currently functions or could ideally function. Flowcharts can help you see whether the steps of a process are logical, uncover problems or miscommunications, define the boundaries of a process, and develop a common base of knowledge about a process. Flowcharting a process often brings to light redundancies, delays, dead ends, and indirect paths that would otherwise remain unnoticed or ignored. But flowcharts don't work if they aren't accurate, if team members are afraid to describe what actually happens, or if the team is too far removed from the actual workings of the process.

There are many varieties of flowcharts and scores of symbols that you can use. Experience has shown that there are three main types that work for almost all situations:

- High-level flowcharts map only the major steps in a process for a good overview.

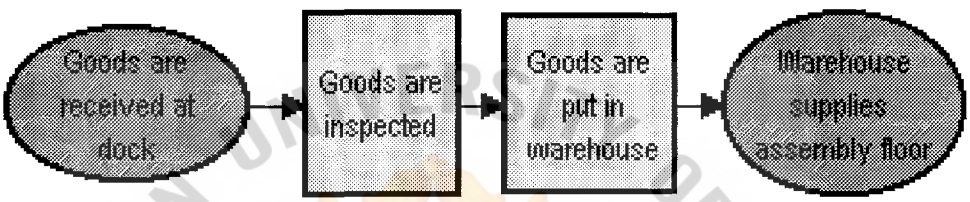


Figure 2.4.1

- Detailed flowcharts show a step-by-step mapping of all events and decisions in a process.

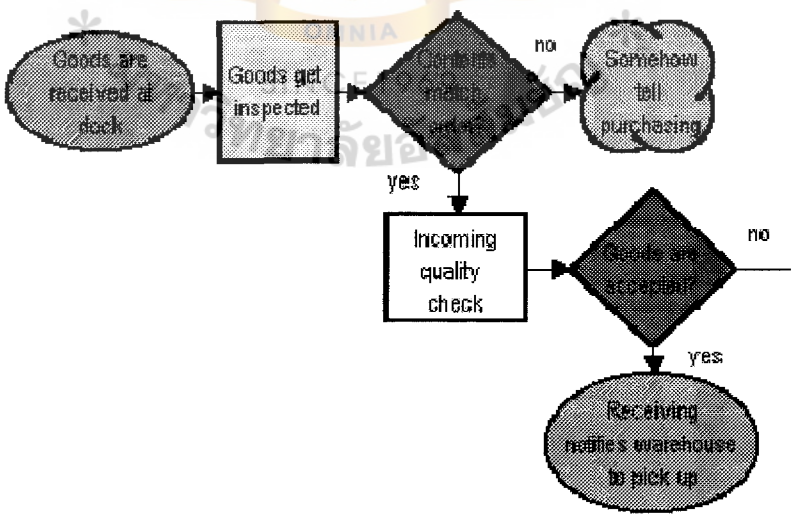


Figure 2.4.2

- Deployment flowcharts which organize the flowchart by columns, with each column representing of a person or department involved in a process.

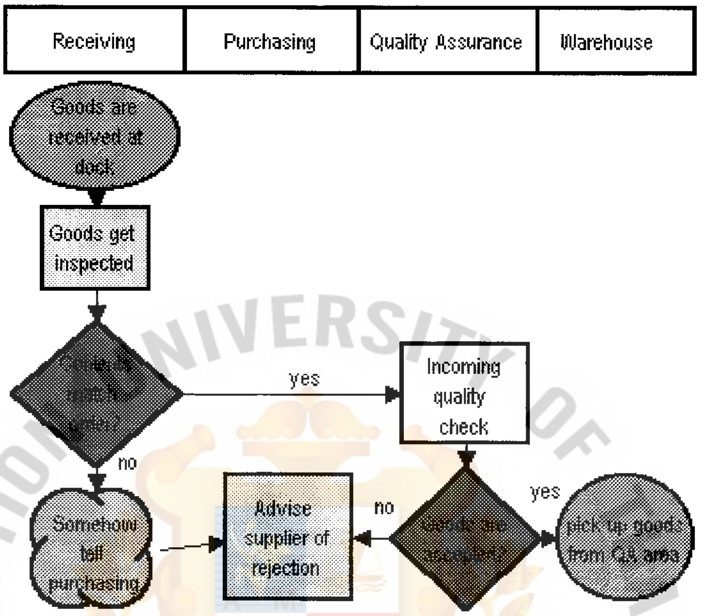


Figure 2.4.3

The trouble spots in a process usually begin to appear as a team constructs a detailed flowchart. Although there are many symbols that can be used in flowcharts to represent different kinds of steps, accurate flowcharts can be created using very few (e.g. oval, rectangle, diamond, delay, cloud).

- To construct an effective flowchart:
- Define the process boundaries with starting and ending points.
- Complete the big picture before filling in the details.
- Clearly define each step in the process. Be accurate and honest.
- Identify time lags and non-value-adding steps.
- Circulate the flowchart to other people involved in the process to get their comments.

Flowcharts don't work if they're not accurate or if the team is too far removed from the process itself. Team members should be true participants in the process and feel free to describe what really happens. A thorough flowchart should provide a clear view of how a process works. With a completed flowchart, you can:

- Identify time lags and non-value-adding steps.
- Identify responsibility for each step.
- Brainstorm for problems in the process.

2.1.6 Histograms

Histograms

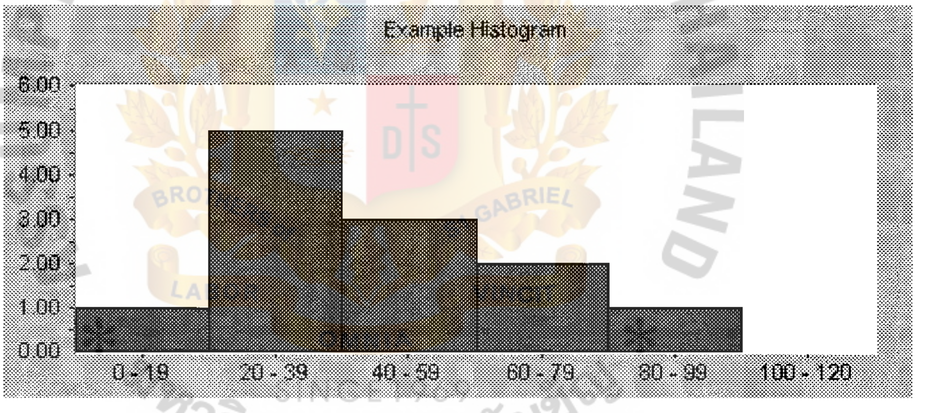


Figure 2.5

A histogram is a specialized type of bar chart. Individual data points are grouped together in classes, so that you can get an idea of how frequently data in each class occurs in the data set. High bars indicate more points in a class, and low bars indicate less points. In the histogram show above, the peak is in the 40-49 class, where there are four points.

The strength of a histogram is that it provides an easy-to-read picture of the location and variation in a data set. There are, however, two weaknesses of histograms that you should bear in mind:

The first is that histograms can be manipulated to show different pictures. If too few or too many bars are used, the histogram can be misleading. This is an area which requires some judgment, and perhaps some experimentation, based on the analyst's experience.

Histograms can also obscure the time differences among data sets. For example, if you looked at data for #births/day in the United States in 1996, you would miss any seasonal variations, e.g. peaks around the times of full moons. Likewise, in quality control, a histogram of a process run tells only one part of a long story. There is a need to keep reviewing the histograms and control charts for consecutive process runs over an extended time to gain useful knowledge about a process

Histogram statistics: For histograms, the following statistics are calculated:

Mean	The average of all the values.
Minimum	The smallest value.
Maximum	The biggest value.
Std Dev	An expression of how widely spread the values are around the mean.
Class Width	The x-axis distance between the left and right edges of each bar in the histogram.
Number of Classes	The number of bars (including zero height bars) in the histograms.
Skewness	Is the histogram symmetrical? If so, Skewness is zero. If the left hand tail is longer, skewness will be negative. If the right hand tail is longer, skewness will be positive. Where skewness exists, process capability indices are suspect. For process improvement, a good rule of thumb is to look at the long tail of your distribution; that is usually where quality problems lie.
Kurtosis	Kurtosis is a measure of the pointiness of a distribution. The standard normal curve has a kurtosis of zero. The Matterhorn, has negative kurtosis, while a flatter curve would have positive kurtosis. Positive kurtosis is usually more of a problem for quality control, since, with "big" tails, the process may well be wider than the spec limits.

Specification Limits and Batch Performance

Where relevant, you should display specification limits on your histograms. The specifications include a target value, an upper limit and a lower limit. For example, if Michael Jordan is shooting a basketball at a hoop, his target is the middle of the hoop. His spec limits are those points in the circle of the hoop that will just allow the ball to bounce through the basket. If the shot is outside spec limits, the ball doesn't go in.

When you overlay specification limits on a histogram, you can estimate how many items are being produced which do not meet specifications. This gives you an idea of batch performance, that is, of how the process performed during the period that you collected data. PathMaker calculates the actual percentage of items in the sample that fall outside specification limits.

When you have added target, upper and lower limit lines, you can examine your histogram to see how your process is performing.

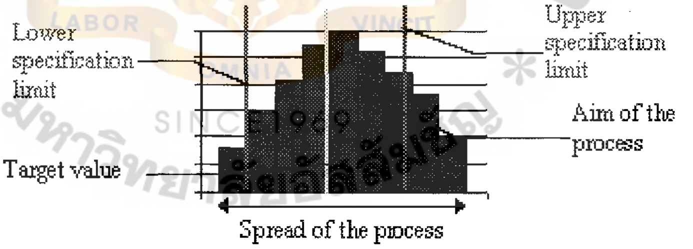


Figure 2.6 Specification Limits and Batch performance

If the histogram shows that your process is wider than the specification limits, then it is not presently capable of meeting your specifications. This means the variation of the process should be reduced.

Also, if the process is not centered on the target value, it may need to be adjusted so that it can, on average, hit the target value. Sometimes, the distribution of a process could fit between the specification limits if it was centered, but spreads across one of the limits because it is not centered. Again, the process needs to be adjusted so that it can hit the target value most often.

Center of a Distribution

Processes have a target value, the value that the process should be producing, where most output of the process should fall. The center of the distribution in a histogram should, in most cases, fall on or near this target value. If it does not, the process will often need to be adjusted so that the center will hit the target value.

Spread of a Distribution

The spread, or width of a process is the distance between the minimum and maximum measured values. If the spread of the distribution is narrower than the specification limits, it is an indication of small variability in the process. This is almost always the goal, since consistency is important in most processes. If the distribution is wider than the specification limits the process has too much variability. The process is generating products that do not conform to specifications, i.e. junk.

Shape: Skewness and Kurtosis

A "normal" distribution of variation results in a specific bell-shaped curve, with the highest point in the middle and smoothly curving symmetrical slopes on both sides of center. The characteristics of the standard normal distribution are tabulated in most statistical reference works, allowing the relatively easy estimation of areas under the curve at any point.

Many distributions are non-normal. They may be skewed, or they may be flatter or more sharply peaked than the normal distribution.

A "skewed" distribution is one that is not symmetrical, but rather has a long tail in one direction. If the tail extends to the right, the curve is said to be right-skewed, or positively skewed. If the tail extends to the left, it is negatively skewed. PathMaker calculates the skewness of a histogram, and displays it with the other statistics. Where skewness is present, attention should usually be focused on the tail, which could extend beyond the process specification limits, and where much of the potential for improvement generally lies.

Kurtosis is also a measure of the length of the tails of a distribution. For example, a symmetrical distribution with positive kurtosis indicates a greater than normal proportion of product in the tails. Negative kurtosis indicates shorter tails than a normal distribution would have. Again, PathMaker calculates the kurtosis of histograms.

Taken together, the values for process center, spread, skewness and kurtosis can tell you a great deal about your process. However, unless you have a solid statistics background, you will probably learn more from looking at the histogram itself than from looking at the statistics. Just remember that, where there is data in the tails near a specification limit, chances are that some non-conforming product is being made. If your process is actually making 5 bad parts in every thousand, and you are sampling 20 in every thousand, it will take some time before you find any out-of-spec parts. There are three things you should do:

- keep tracking data
- get help in fitting a curve to your distribution
- make sure your sampling plan is efficient.
- Path Maker can help with the first, but not (yet) with the other two.
- Distributions you may encounter

- The standard normal distribution, with its zero skewness and zero kurtosis.

Figure 2.7 Specification Limits and Batch performance

A skewed distribution, with one tail longer than the other.

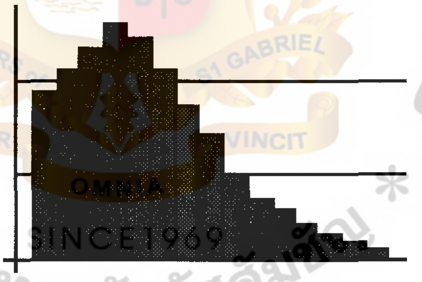


Figure 2.7.2 Specification Limits and Batch performance

A double-peaked curve often means that the data actually reflects two distinct processes with different centers. You will need to distinguish between the two processes to get a clear view of what is really happening in either individual process.

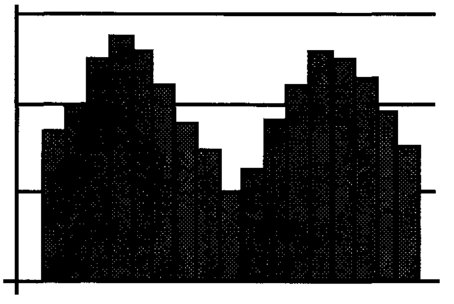


Figure 2.7.3 Specification Limits and Batch performance

A truncated curve, with the peak at or near the edge while trailing gently off to the other side, often means that part of the distribution has been removed through screening, 100% inspection, or review. These efforts are usually costly and make good candidates for improvement efforts.

Figure 2.7.4 Specification Limits and Batch performance

A plateau-like curve often means that the process is ill-defined to those doing the work, which leaves everyone on their own. Since everyone handles the process differently, there are many different measurements with none standing out. The solution here is to clearly define an efficient process.

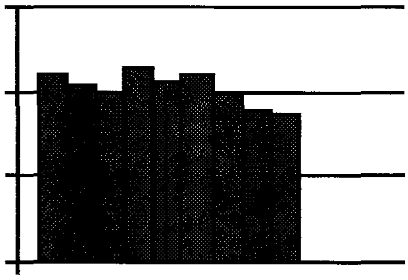


Figure 2.7.5 Specification Limits and Batch performance

Outliers in a histogram – bars that are removed from the others by at least the width of one bar – sometimes indicate that perhaps a separate process is included, but one that doesn't happen all the time. It may also indicate that special causes of variation are present in the process and should be investigated, though if the process is in control before the histogram is made as it should be, this latter option is unlikely.

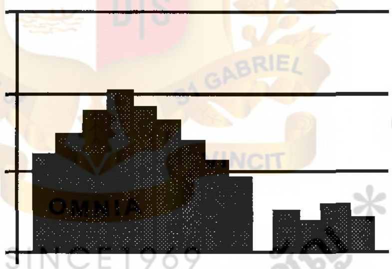


Figure 2.7.6 Specification Limits and Batch performance

2.1.7 Statistical Process Control (SPC)

Statistical Process Control monitors standards, makes measurements, and takes corrective action as a product or service is being produced. Samples of process outputs are examined; if they are within acceptable limits, the process is permitted to continue. If they fall outside certain specific ranges, the process is stopped and, typically, the assignable cause located and removed. Control charts are graphic presentations of data over time that show upper and lower limits for the process we want to control. Control charts are constructed in such a way that new data can be quickly compared to past performance data.

We take samples of the process output and plot the average of these samples on a chart that has the limits on it. The upper and lower limits in a control chart can be in units of temperature, pressure, weight, length, and so on. More details in SPC will be discussed in the next section.

2.2 The Role of Inspection

To make sure a system is producing at the expected quality level, control of the process is needed. The best processes have little variation form the standard expected. The operations manager's task is to build such systems and to verify, often by inspection, that they are performing to standard. This inspection can involve measurement, tasting, touching, weighing, or testing of the product (sometimes even destroying it when doing so)$_T$ Its goal is to detect a bad process immediately. Inspection does not correct deficiencies in the system or defects in the products; nor does it change a product or increase its value. Inspection only finds deficiencies and defects, and it is expensive.

Inspection should be thought of as an audit. Audits do not add value to the product. However, operations managers, like financial managers, need audits, and they need to know when and where to audit. So there are two basic issues relating to inspection;

(a) when to inspect and

(b) where to inspect.

Deciding when and where to inspect depends on the type of process and the value added at each stage. Inspections (audits) can take place at any of the following points:

(1) At your supplier's plant while the supplier is producing.

(2) At your facility upon receipt of goods from your supplier.

(3) Before costly or irreversible processes.

(4) During the step-by-step production process.

(5) When production or service is complete.

(6) Before delivery form your facility.

(7) At the point of customer contact.

2.3 Inspection of Attributes vs. Variables

When inspections take place, quality characteristics may be measured as either attributes or variables. Attribute inspection classifies items as being either good or defective. It does not address the degree of failure. Variable inspection measures such dimensions as weight, speed, height, or strength to see if an item falls within an acceptable range If a piece of electrical wire is supposed to be 0.01 inch in diameter, a micrometer can be used to see if the product is close enough to pass inspection.

Knowing whether attributes or variables are being inspected helps us decide which statistical quality control approach to take, as shown in the next section.

2.4 Statistical Process Control (SPC)

SPC is the basic tool for observing variation and using statistical signals to monitor and/or improve performance. This tool can be applied to nearly any area.

- Performance characteristics of equipment
- Error rates of bookkeeping tasks
- Dollar figures of gross sales
- Scrap rates from waste analysis
- Transit times in material management systems
- SPC stands for Statistical Process Control. Unfortunately, most companies apply it to finished goods (Y's) rather than process characteristics (X's).
- Until the process inputs become the focus of our effort, the full power of SPC methods to improve quality, increase productivity, and reduce cost cannot be realized.

SPC is a statistically based method of:

1. Objectively evaluating the performance (stability) of process and product variables
2. Pointing out the existence of special causes of variation
3. After removing the special causes, maintaining expected processing despite normal process variation
   - All processes have natural variability (due to common causes) and unnatural variability (due to assignable causes). We use SPC to monitor and/or improve the process. While control charts can indicate special causes through Out-of-Control signals, they cannot tell you why the process is out of control.

- Control charts are the means through which process and product parameters are tracked statistically over time. Control charts incorporate upper and lower control limits that reflect the natural limits of (random) variability. These limits must not be improperly compared to the customer specification limits.
- Control limits are based on establishing + 3s mean limits for X or Y.
- Based on statistical principles, control charts allow for the identification of unnatural (nonrandom) patterns: special causes have changed the process.

Steps to Construct a Control Chart

(a) Choose the quality characteristic to be charted. In making this choice, there are several things to consider:

(b) Choose a characteristic that is currently experiencing a high number of nonconformities or items that do not conform. A. Pareto analysis is useful to assist the process of making this choice.

(c) Identify the process variables contributing to the end-product characteristics to identify potential charting possibilities.

(d) Choose characteristics that will provide appropriate data to identify and diagnose problems. In choosing characteristics, it is important to remember that attributes provide summary data and may be used for any number of characteristics. On the other hand, variables data are used for only one characteristic on each chart but are necessary to diagnose problems and propose action on the characteristic.

(e) Determine a convenient point in the production process to locate the chart. This point should be early enough to prevent nonconformities and to guard against additional work on nonconforming items.

(f) Choose the type of control chart.

(g) The first decision is whether to use a variable chart or an attributes chart A variables chart is used to control individual measurable characteristics, whereas an attributes chart may be used with go no-go type of inspection. An attributes chart is used to centre! Percentage or number of nonconforming items or number of nonconformities per item. A variables chart provides the maximum amount of information per item inspected. It is used to control both the level of the process and the variability of the process. An attributes chart often provides summary data that can be used to improve the process by then controlling individual characteristics.

(h) Choose the specific type of chart to be used. If a variables chart is to be used, decide whether the average and range or the average and standard deviation are to be charted. If small shifts in the mean are important, a cumulative sum or exponentially weighted moving average chart may be used. The disadvantage of these two latter charts is that they are more difficult for the practitioner to use and understand. If subgroups are not possible, individual readings may be used, but these are to be avoided if possible. For attributes charts, the percentage nonconforming or number of nonconforming items may be preferable.

(i) Choose the center line of the chart and the basis for calculating the control limits. The center line may be the average of past data, the average of data yet to be collected, or a desired (standard) value. The limits are usually set at ±3 standard deviations, but other muliples of the standard deviation may be used for other risk factors. The use of 3 standard deviations results in a negligible risk of looking for problems that do not exist, i.e., false alarms. However, this multiple may result in an appreciable risk of failing to detect a small shift in the parameter being studied. Smaller multiples increase the risk of looking for a false alarm but reduce the risk of failing to detect a small shift. The fact that it is usually much more expensive to look for problems that do not exist than to miss some small problems is the reason that the ±3cr limits are usually chosen.

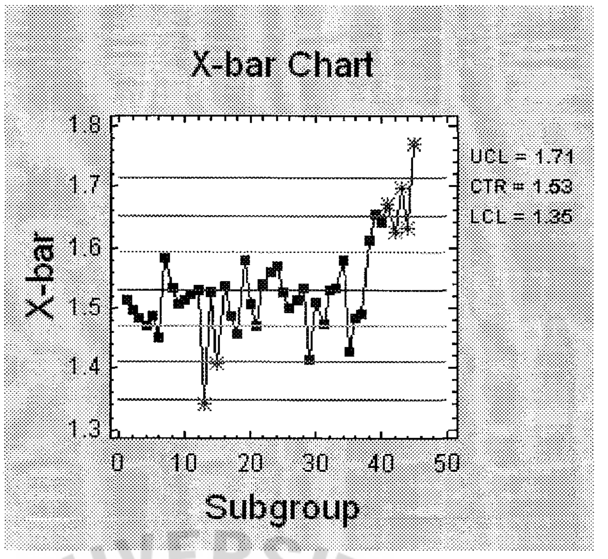
(j) Choose the rational subgroup or sample. It should be pointed out that the term sample is usually used, but sample could mean an individual value, and samples of more than one are desirable for control charts if feasible. For variables charts, samples of size 4 or 5 are usually used, whereas for attributes charts, samples of 50 to 100 are often used. Attributes charts in fact may be used with 100 percent inspection as a reflection of the underlying process involved. In addition to the size of the sample, the samples should be selected in such a way that the chance of a shift in the process is minimized during the taking of the sample (thus a small sample should be used); whereas the chance of a shift, if it is going to occur, is at a maximum between samples. This is the concept of rational subgrouping. Thus it is better to take small samples periodically than to take a single large sample. Experience is usually the best method for deciding on the frequency of taking samples.

(k) Provide a system for collecting the data. If control charts are to become shop tools, the collection of data must be an easy task. Measurement must be made simple and relatively free of error. Measuring instruments must give quick and reliable readings. If possible, the measuring instrument actually should record the data, since this will eliminate a common source of errors. Data sheets should be designed carefully to make the daia readily available. The data sheets must be kept in a safe and secure place, free from dirt or oil.

(l) Calculate the control limits and provide adequate instructions to all concerned on the meaning and interpretation of the results. Production personnel must be knowledgeable and capable of performing corrective action when the charts indicate it. After considering all six steps above, the control chart can be constructed. As mentioned the control charts are separated into two main types, which are: variables chart and attributes chart. However, in this project only the attributes chart will be used to determine the process characteristics. So in this section the control charts for attributes will be discussed more.

Control Charts for Variables

The classical type of control chart, originally developed back in the 1930's, is constructed by collecting data periodically and plotting it versus time. If more than one data value is collected at the same time, statistics such as the mean, range, median, or standard deviation are plotted. Control limits are added to the plot to signal unusually large deviations from the centerline, and run rules are employed to detect other unusual patterns.



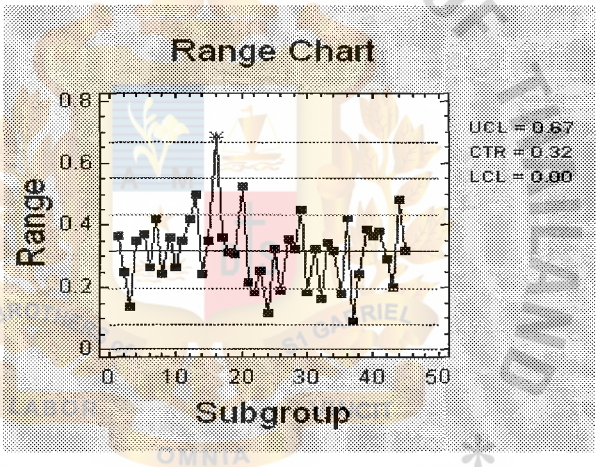


Figure 2.8 Control Charts for Variables

Variables are characteristics that have continuous dimensions. They have an infinite number of possibilities. Examples are weight, speed, length, or strength. Control charts for the mean and the range, R, are used to monitor processes that have continuous dimensions. The x chart tells us whether changes have occurred in the central tendency (the mean, in this case) of a process. These changes might be due to such factors as tool wear, a gradual increase in temperature, a different method used on the second shift, or new and stronger materials.

The R-chart values indicate that a gain or loss in dispersion has occurred. Such a change might be due to worn out bearings, a loose tool, an erratic flow of lubricants to a machine, or to sloppiness on the part of a machine operator. The two types of charts go hand in hand when monitoring variables, because they measure the two critical parameters, central tendency and dispersion.

Control Charts for Attributes

Many quality characteristics cannot be conveniently represented numerically. In such cases, each item inspected is classified as either conforming or nonconforming to the specifications on that quality characteristic. Quality characteristics of this type are called attributes. Examples are nonfunctional semiconductorchips.

p charts

This chart shows the fraction of nonconforming or defective product produced by a manufacturing process. It is also called the control chart for fraction nonconforming.

c charts

This shows the number of defects or nonconformities produced by a manufacturing process.

u charts

This chart shows the nonconformities per unit produced by a manufacturing process.

Control charts for variables ($\bar{x}$ and R charts) require actual measurements, such as length, weigh[1], tensile strength, etc. Thus the sampling attributes, which are typically classified as defective or nondefective, cannot be used for such charts. Charts for attributes, on the other hand, can be used in situations where we only wish to count the number of nonconforming items or the number of nonconformities in a sample. There are several advantages of attributes charts over variables charts.

(a) Attributes charts can be used to cover many different nonconformities at the same time, whereas a separate chart must be used for each quality characteristic with variables charts.

(b) The inspection required for attributes charts may be much easier than that for variables charts. We merely need to know if the item being inspected meets the specified requirements.

(c) Attributes charts may be used for visual inspections for such attributes as cleanliness, correct labeling, correct color, and so on.

(d) Attributes charts do not depend on an underlying statistical distribution.

On the other hand, variables charts need a much smaller sample size. In the case of the charts discussed earlier, sample sizes of only 4 or 5 will be used, whereas attributes charts would require sample sizes of at least 50. Attributes control charts are often used for 100 percent inspection, whereas this would be difficult for variables charts. The most common control charts for attributes are the p chart for percentage nonconforming, the np chart for number of nonconforming items, the c chart for number of nonconformities, and the u chart for number of nonconformities per item. Each of these charts will be discussed in order.

Control Charts for Percentage Nonconforming (p)

The variable to be controlled here is the percentage or fraction of each sample that is nonconforming to the quality requirements. Thus the number of inspected items containing one or more nonconformities is divided by the number of items inspected. This is the fraction nonconforming. Sometimes this ratio is multiplied by 100, and the variable plotted is the percentage nonconforming. Assuming that the process is constant, the underlying distribution would be the binomial distribution. For relatively large samples, the binomial distribution can be approximated adequately by the normal distribution, and as with the control charts for variables, virtually all the data should then fall within 3 standard deviations of the mean. If data fall outside these 3 standard deviation limits, this would indicate a lack of statistical control. Therefore, the control limits are set at these values.

The standard deviation of a binomial variable is

$$\sigma_p = \sqrt{\frac{p(1-p)}{n}}$$

Therefore, the upper and lower control limits for a p chart will be at

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

Where σ = the process standard deviation

n = the sample size

Although the p chart is usually used for defective - nondefective types of inspection, it also may be used for measurement inspection. Here a piece being inspected is considered nonconforming if its measurements are outside a set of specified limits. However, this use of the p chart is not recommended because it is less able to diagnose causes on nonconformities.

A p chart may be used when the sample size is constant or not constant. Since the n in the preceding expression for the control limits is the sample size, if n varies from subgroup, as is often the case when the chart is used to plot 100 percent inspection data, the control limits will vary. They will be wider for small subgroups than for large ones. If the subgroup size varies, we have three possibilities.

1) We can calculate the average size of the subgroups. This is appropriate when the sizes are similar or all data lie near the centerline.
2) We can calculate separate control limits for each subgroup. This might lead to a rather confusing appearing chart.
3) We can find the average subgroup size and use the resulting control limits, but when a point falls near the limits, calculate the actual limits using the actual subgroup size.

The third approach is the recommended one. In using it, we must remember that a subgroup size larger than the average will mean the limits move in toward the centerline, so if a point lies outside the limits based on the average n, there is no point in calculating a new limit.

In setting up a p chart, we would, as for variables charts, collect 20 to 25 samples over enough time to allow the process to change. If the sample sizes are equal, we would determine the number of nonconforming items in each sample, divide each by the subgroup size, and average them. This is the p in the preceding expression for the control limits. In finding this average p, we first add all the numbers of nonconforming items and the numbers of items inspected in each subgroup. Then we divide the first total by the second to get the average. This procedure is essential if the subgroup size changes. As an example to show the importance of this procedure, suppose that we have five lots of a finished product as shown in Table 1. N is the lot size, x is the number of nonconforming items in each lot, and p is the fraction nonconforming. We are inspecting all items in each lot.

Table 2.1 Inspection Results of 5 Lots.

Lot	N	X	P
1	500	32	0.064
2	50	10	0.200
3	800	10	0.013
4	100	18	0.180
5	150	20	0.133
Totals	1600	90	0.590

If we simply average the fraction nonconforming values in the right hand column, we would get a value for $\bar{p}$ of 0.590/5 =0.118. This would give us upper control limits, using the actual lot sizes of 0.161, 0.255, 0.152, 0.215, and 0.197. None of the lots are out of control. However, if we instead find $\bar{p}$ as 90/1600 = 0.056, we get upper control limits of 0.087, 0.154, 0.081, 0.458, and 0.113. In this case, three of the five lots (lots 2, 4. and 5) are above the upper control limit, indicating that this does not represent a stable process. The true average fraction nonconforming is 0.056 not 0.118. The latter gives equal representation to each lot despite their widely differing sizes.

For all types of control charts for attributes, the lower control limit, when calculated using the appropriate expressions, may turn out to be negative. This of course, makes no sense, so we simply do not have a lower control limit in these cases. In the preceding example, this applies to lots 2, 4. and 5. Note that lot 3 is actually below its lower control limit, which is, in this case. 0.032. This means that the quality, measured in terms of fraction nonconforming, is better than the average of the other lots. Some people use zero as lower control limit when the calculated limit is negative.

This might lead to mistaken notion that a sample value of zero means that the subgroup is not in control.

Control Charts for Number of Nonconforming Items (np)

In this case we plot the number of nonconforming items in each subgroup. Since p is x/n, x is equal to np, where x is the number of nonconforming items in a sample, and the chart is often called as np chart. For this type of chart, we must have a constant subgroup size. In this case the control limits are set at:

$$n\bar{p} \pm 3\sqrt{n\bar{p}(1-\bar{p})}$$

or, using . the average number of nonconformities per subgroup, the control limits may be stated equivalently as:

$$\bar{x} \pm 3\sqrt{\bar{x}\left(1-\frac{\bar{x}}{n}\right)}$$

Control Charts for Number of Nonconformities (c)

If we wish to plot the number of nonconformities, where each item inspected may have several nonconformities and each nonconformity is counted, we have a c chart, where c is the number of nonconformities in each sample. In this case, the underlying distribution is the Poisson distribution. The standard deviation of this distribution is the positive square root of the mean, so if we again take 20 to 25 samples and calculate the average number of nonconformities, c , the control limits will be set at:

$$\bar{c} \pm 3\sqrt{\bar{c}}$$

A c chart requires an equally large number of opportunities for a nonconformity to occur in each subgroup inspected. Thus, for example, if we are inspecting the number of defective solder connections in each circuit board, they must all have the same number of connections. If not, we must use the u chart, to be discussed next.

2.4.7 Control Chart for Number of Nonconformities per Item (u)

This chart is sometimes called a standardized c chart. It is used when more than one item makes up a sample but each item may have more than one nonconformity. The variable plotted on the chart is the number of nonconformities per item. Thus the number of items in a sample does not need to remain constant, as it does for the c chart. The control limits are calculated similarly to those for a c chart except that the variable is c/n, where n is the number of items in the sample. For example, if we are inspecting for defective solder joints on printed circuit' boards where the boards have different numbers of solder connections, we would divide the number of nonconforming solder connections on each board by the number of connections on that board.

The control limits for a u chart are set at:

$$\bar{u} \pm 3\sqrt{\frac{\bar{u}}{n}}$$

Run Test

A tool called a run test is available to help identify the kind of abnormalities in a process. In general, a run of 5 points above or below he target or centerline means that an assignable, or nonrandom, variation is present. When this occurs, even though all the points may fall inside the control limits, a flag has been raised. This means the process is not statistically in control. The following are the patterns that we have to observe for the abnormal of the process:

a) One plot out above (or below) the control limit. Investigate for cause.
b) Trends in either direction (increase or decline), 5 plots. Investigate for cause of progressive change.
c) Two plots near lower (or upper) control. Investigate for cause.
d) Run of 5 above (or below) central line. Investigate for cause.
e) Erratic behavior. Investigate.

III. INSPECTION PROCESS DESIGN METHODOLOGY

3.1 Inspection Process Design Methodology

In this project study, the steps to do the study are determined as follows:

(1) Observing and collecting information of the production processes of the Signal cable product. Collecting the essential raw data that is necessary for this study.

(2) Interviewing persons in charge of production line for the experience of quality erroneousness.

(3) Determine the production process that should be used to apply SPC for study.

(4) Gather the data and using "Excel OM 2 software to calculate the control limit and plot the control chart.

(5) Determine the characteristic of the control chart.

3.2 Observation of the Production Processes

In this step the information of the production processes will be gathered by Interviewing the person in charge in each process and also directly observing the materials flow in the processes. The production processes are divided into six main processes The description of the defective products that found in each process is shown in the following section.

3.3 Description of the Nonconforming Output of the Processes

As mentioned earlier that this study project will concentrate only on the Signal cable product, the lists of these defects are gathered from the six steps of the production processes. From observing the output of the production processes, the defects can be described as follows:

(1) Drawing

i. Rough Surface

ii. Discoloration

(2) Bunching

i. Cannot keep diameter & length In specification

(3) Insulation

i. Printing not clear

ii. Essentric 〈 80%

iii. Dirty

(4) Stranding

i. Cannot keep Diameter and tension to make standard condition

(5) Shielding

i. Scew error

(6) Jacketing

i. Diameter (Over or less than DWG)

ii. Wrong Material

3.4 Selecting the Process to Be Observed

After gathering the data and information from every production processes, the most critical process in the production line should be selected - i.e. the process where products have a lot of defects. Then we will apply SPC to this process to analyze its characteristics.

3.5 Existing Inspection System

The existing inspection system did not design a procedure to keep a record of the defective products. So they cannot see the trends or the characteristics of the process.

3.6 Proposed System

The proposed system would still remain the existing system, and also add some other SPC processes. The additional SPC related processes are

(1) Keep the record of the defective data.

(2) Construct the Control Chart to see the characteristic of the coach Process.

(3) Sampling the finished product and construct the Control Chart to see the erroneous of the existing inspection process.

(4) Construct the Cause-and-effect diagram to determine the cause of the defects.

3.7 Inspection Design

The inspection processes can be divided into four main parts, which are determining the product to be studied, determining the sample size, collecting data, and the last one is analyzing data. The details of each step is discussed below.

(1) Determining Product to be studied: as mentioned earlier there are many

Signal cable models and the difficulty to produce the output for each model is not the same. Some models can have a lot of defective outputs, while others have very few. So in this study we will choose the model that frequently ordered and has a lot of defects.

Remark: Each model also has many sizes, however the difficulty of the production is not much different,

(2) Determining the sample size: the sample size of the attributes control chart should big enough so that the result can be reliable. And the frequency for sampling the sample should be short enough so that we can see the shift in the process if it occurs.

(3) Collecting data: the data collecting model should be designed so that we can keep a record of the defective items appropriately.

(4) Analyzing data: the collected data is analyzed by using the "Excel" and software. They will calculate the control limit and also plot the control chart.

3.8 Excel OM 2 Software

Excel OM version 2 is an application software that comes together with the operation management textbook - Operation Management sixth edition, by Jay Heizer and Barry Render, Excel OM Version 2 is created by Howard J. Weiss. It is an add-in software for Microsoft Excel. There a lot of modules related to the operation management such as quality control, forecasting, production layout, etc. Additionally, it can show the graphical information of the collected data, which is also created in an Excel worksheet. The p-charts can be created by the following procedure:

(1) Enter the number of defective units per sample.

(2) Enter the sample size and z-value.

(3) Enter the number of the defects found in each sample.

(4) Then the percentage of defects, upper control limit, lower control limit, and central line will be calculated. The calculation of the Excel OM2 is using the following formula: For each sample;

(a) Percent defective = Number defective/sample size

(b) Total Sample Size = Number of samples * sample size

(c) Total Defects = Sum of defect column (SUM)

(d) Percentage defects = Total defects/Total sample size

(e) Std deviation of p-bar = Square root((l-percentage defects) * percentage defects)/sample size)

(f) Upper Control Limit = percentage defects + 3 * std deviation of p-bar

(g) Center Line = percentage defects

(h) Lower Control Limit = percentage defects – 3 * std deviation of p- bar if this is positive, else 0 (IF)

(5) Then the control chart would be plotted.

IV. DETERMINING THE PRODUCTION PROCESS

This chapter will discuss the information gathered for this project study. First, we gather the information of the defective production process and use it to plot a Pareto chart. Second, we determine the process that seems to be the critical process, so that we will use it for this project. After that we will gather the data of defective goods and use it to plot the control charts and analyze it.

4.1 Determining the Defective Items' Information

Data show in this section comes from observing the production processes and interviewing the persons in charge in each process. So these data is an estimated data. There are three Pareto charts shown in this chapter. First, Figure 4.1 shows the chart of the entire Production Process of the Signal cablb product. It shows the defects that come from each step of the production process. As seen from the chart, the Insulation process is the highest step that produces the defects. This process is the most interesting process to apply SPC technique to see its characteristics.

Table 4.1. Cumulative Percentage of Pareto Chart.

Class Label	Rank	Count	Percent	Cum. percent
Insulation process	1	77	77.0	77.0
Jacketing process	2	10	10.0	87.0
Buncher	3	5	5.0	92.0
Stranding	4	3	3.0	95.0
Drawing	4	3	3.0	98.0
Shielding	5	2	2.0	1 00.0

The production processes is divided into six main processes (see Figure 1.2).

From the information that we gathered, we found that the most critical process thatshould be used for this study is the third step (Insulation process), as seen in the Pareto chart. It is the process that can be found to be most obviously the defective output.

processes -Drawing Shielding Stranding process - are not the complicated processes. There are not many variables that could affect these processes. These three processes are just preparing and transforming the raw materials to the appropriate form to serve as the input for the Insulation & Jacketing process. While the stranding process can be effected by many variables such as the temperature that apply to the worker the pressure of the machine, the difficulty of the Signal cable, the experience of the workers, etc. All of these variables can cause the output product to be defective.

In the observation of the production processes, the data of the defects found in every processes should be gathered to plot the Pareto Chart to present the graphically information. The second chart Figure 4.2, shows the Pareto chart by type of defects.

Table 4.2. Cumulative Percentage of Pareto Chart

Class Label	Rank	Count	Percent	Cum. Percent
Printing	1	39	39.0	39.0
Essentric	2	28	28.0	67.0
Dirty	3	10	10.0	77.0
Diameter	4	6	6.0	83.0
Wrong materials	5	4	4.0	87.0
Rough	6	2	2.0	89.0
Thickness error	7	2	2.0	91.0
Scew error	8	2	2.0	93.0
Others	9	7	7.0	100.0

The first three in the rank are the defects found in the Insulation process. They are totally 80% of all the defects found in this production process. So it obviously shows that if we can control and reduce these defects, the whole process will be much better.

4.2 Selecting the Process to Be Observed

After gathering the data and information from every production processes, it shows that the most critical process is the Insulation Process. Since it has a lot of variable that cause the effect to the output product. And from the nonconforming product's list (in previous section) show that the Insulation Process is the process that can cause a lot of nonconforming products. So the Insulation Process will be chosen to apply the SPC technique. And the control chart will be constructed to see the process' characteristic. After that the Cause-and-effect diagram will be used to determine the cause of the detect.

4.3 Existing Inspection System of the Insulation Process

At present, the output product from the Extruder machine is not directly inspected by the specific person. It is inspected by the persons whose duty is cutting the exceed bought signal cable , and also observing for defective product. This job is in the sixth step of the production process (see Figure 1.2: Production

Process). However, from observing and randomly rechecking the output product for gathering the data for this study project, we found that most of the defective products can be detected from this inspection process. But another factor that should be considered is the performance (to detect the defects) of the worker, since there are around six persons assigned for this work.

4.4 Determining the Product and Sample Size for Applying SPC

As mentioned there are many models of the shoe-sole produced in this line production. And the number of defective products found in each model is different. So in this project study, only one model is decided to use to determine its characteristics. The model that we select has code 912620195"

The working hour for the Insulation process of 912620195 model is 14 hours a day (8 AM to 10 PM), and 6 days a week (Mon. to Sat.).Every hour

The sample size of 80 m. for every 2 hours is used. And the np-chart will be plotted every week for four weeks. So every chart will have 42 subgroups plotted

(6 days * 1 subgroups/day = 42 subgroups). Then all charts will be used to compare the difference.

4.5 Description of the Product to Be Observed

The product that is used for this study is a Signal cable model 912620195 The specification of this product is as follows:

(a) Product Code 912620195

(b) Color: black

(c) Description: USB

V. IMPLEMENTATION OF STATISTICAL PROCESS CONTROL

5.1 Overview

The Statistical Process Control (SPC) technique will be used to determine the molding process of the Signal cable production process. The data will be plotted in the np-chart every week separately for four weeks, and it will be used for analyzing and discussing their characteristics.

The information of the SPC that is used for this project is listed as follows:

(a) number of subgroups = 42 subgroups

(b) sample size (n) = 80 pieces

(c) chart type = np-chart

After the defectives'data is gathered, it will be entered into the Excel OM2 software. These applications will calculate the control limit (upper control limit, lower control limit, and center line) and show the information of the chart such as total number of defects found, standard deviation of the process, etc. After that the control charts (np-chart) will be plotted. Then it will be used to analyze the control charts to see whether there are any points on the charts are in violation of pattern analysis rules. And we can conclude from the analysis information that the process is in control or not. The following sections will show the information that we got for this project study. The data will be used to calculate and plot the control chart separately for each week.

5.2 Constructing the Control Charts

Table 5.1 Defective of Week 1 .

Subgroup no.	Defectives
1	7
2	6
3	0
4	5
5	5
6	4
1	12
8	2
9	9
10	6
11	4
12	7
13	6
14	4
15	6
16	6
17	6
18	5
19	8
20	5
21	9

Table 5.1 Defective of Week 1. (Continued)

Subgroup no.	Defectives
22	8
23	6
24	4
25	7
26	3
27	5
28	8
29	6
30	6
31	5
32	5
33	7
34	4
35	4
36	7
37	8
38	8
39	8
40	9
41	4
42	9

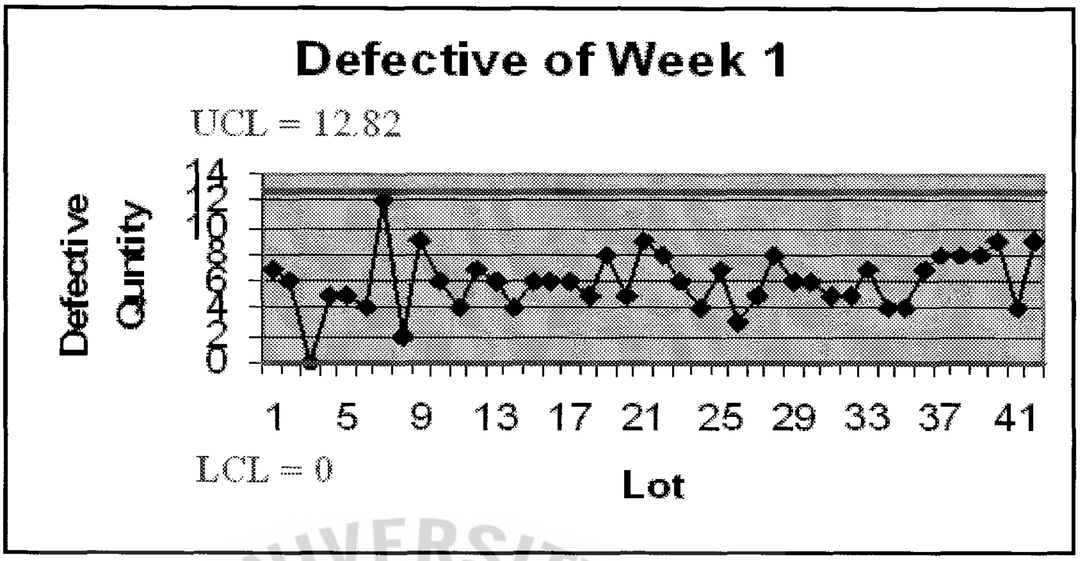


Figure 5.1 Summary Defective for Week 1

Descriptive Statistics for Week 1

Count	=	42
Sum	=	253
Upper Control Limit (UCL)	=	12.82312
Lower Control Limit (LCL)	=	0
Center Line (CL)	=	6.41556
Standard Deviation	=	2.53557
Minimum Value	=	0
Maximum Value	=	12
Range	=	12

Analysis result: None of the data points are in violation of pattern analysis rules.

Table 5.2 Defective Items of Week 2.

Subgroup no.	Defectives
1	3
2	7
3	0
4	4
5	4
6	3
7	7
8	4
9	3
10	3
11	8
12	4
13	5
14	4
15	7
16	3
17	0
18	6
19	8
20	3
21	6

Table 5.2 Defective Items of Week 2. (Continued)

Subgroup no.	Defectives
22	6
23	8
24	7
25	5
26	5
27	8
28	10
29	8
30	6
31	5
32	3
33	8
34	9
35	9
36	10
37	12
38	7
39	2
40	2
41	5
42	2

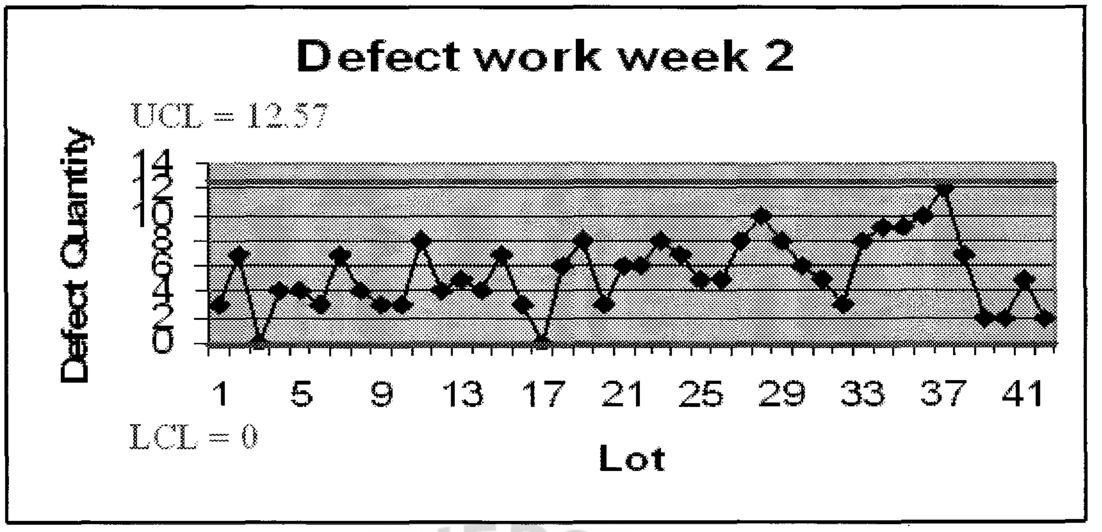


FIgure 5.2 Summary Defective Item for week 2

Descriptive Statistics for Week2

Count	=	42
Sum	=	242
Upper Control Limit (UCL)	=	12.57788
Lower Control Limit (LCL)	=	0
Center Line (CL)	=	6.28894
Standard Deviation	=	2.4558
Minimum Value	=	0
Maximum Value	=	12
Range	=	12

Analysis result: None of the data points are in violation of pattern analysis rules.

Table 5.3 Defective Items of Week 3.

Subgroup no.	Defectives
1	6
2	7
3	4
4	7
5	11
6	5
7	4
8	6
9	4
10	7
11	8
12	4
13	6
14	9
15	9
16	6
17	6
18	6
19	7
20	8
21	13

Table 5.3 Defective Items of Week 3. (Continued)

Subgroup no.	Defectives
22	7
23	9
24	9
25	5
26	6
27	7
28	9
29	2
30	9
31	6
32	9
33	8
34	7
35	8
36	7
37	6
38	6
39	8
40	7
41	10
42	6

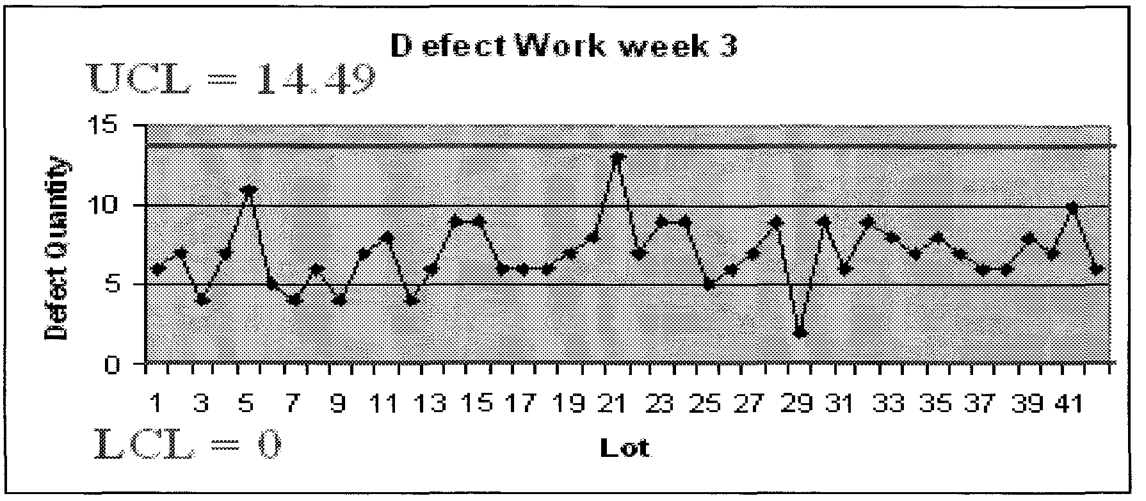


Figure 5.3 Summary Defective Item for Week 3

Descriptive Statistics for Week3

Count	=	42
Sum	=	293
Upper Control Limit (UCL)	=	14.49751
Lower Control Limit (LCL)	=	0
Center Line (CL)	=	7.24875
Standard Deviation	=	1.82457
Minimum Value	=	2
Maximum Value	=	13
Range	=	11

Analysis result: None of the data points are in violation of pattern analysis rules.

Table 5.4 Defective Items of Week 4.

Subgroup no.	Defectives
1	4
2	6
3	2
4	6
5	7
6	4
7	6
8	7
9	7
10	4
11	3
12	2
13	9
14	4
15	5
16	0
17	6
18	4
19	3
20	4
21	5

Table 5.4 Defective Items of Week 4. (Continued)

Subgroup no.	Defectives
22	7
23	6
24	4
25	5
26	5
27	4
28	6
29	4
30	7
31	3
32	6
33	7
34	6
35	4
36	2
37	7
38	3
39	1
40	6
41	3
42	6

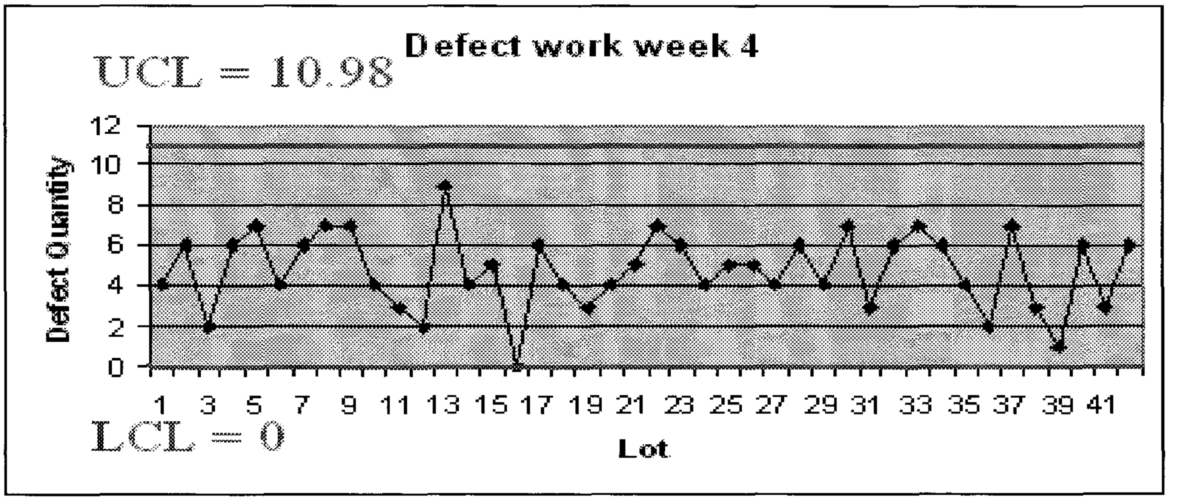


Figure 5.4 Summary Defective Item for Week 4

Descriptive Statistics for Week 4

Count	=	42
Sum	=	200
Upper Control Limit (UCL)	=	10.98534
Lower Control Limit (LCD)	=	0
Center Line (CL)	=	5.49267
Standard Deviation	=	1.91
Minimum Value	=	0
Maximum Value	=	9
Range	=	9

Analysis result: None of the data points are in violation of pattern analysis rules.

5.3 Summary of the SPC Information

Table 5.5 Summary of the Statistics of All Weeks.

	Weekl	Week2	Week3	Week4
Count Sum	42 (253)	42 (242)	42 (293)	42 (200)
UCL	12.82312	12.57788	14.49751	10.98534
LCL	0	0	0	0
CL	6.41556	6.28894	7.24875	5.49267
Std. Deviation	2.53557	2.4558	1.82457	1.91
Min. Value	0	0	2	0
Max. Value	12	12	13	9
Range	12	12	11	9
Analysis result	in control	in control	in control	in control

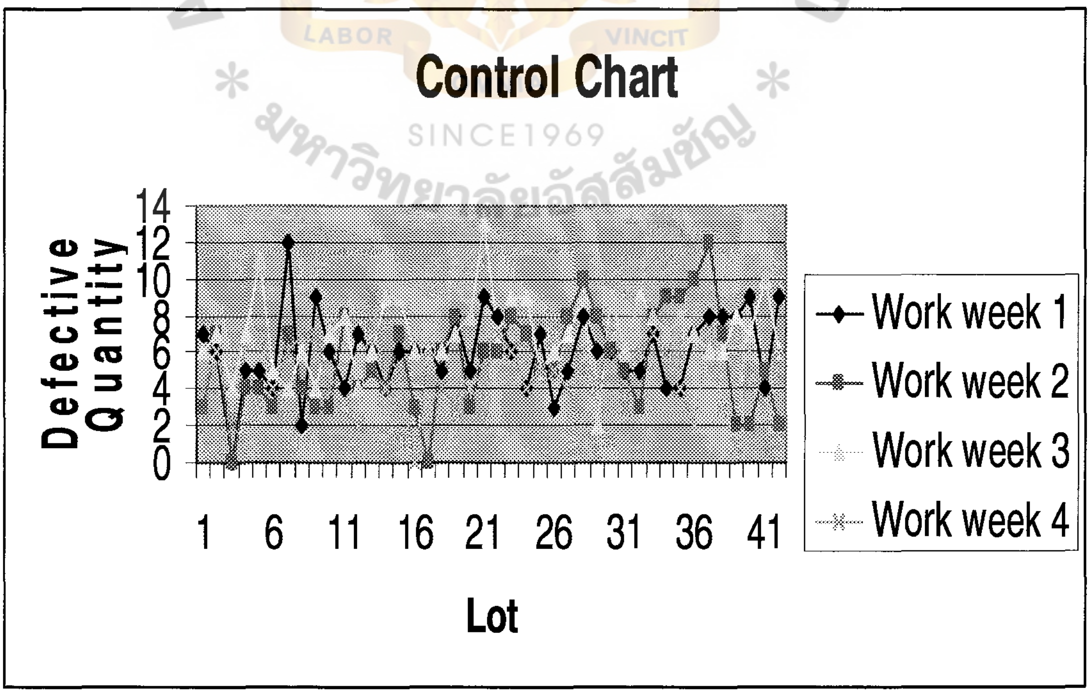


Figure 5.5 Summary defective for week1-4

5.4 RESULT & FINDING

This chapter will discuss the result that comes from the previous chapter. First, from Pareto chart the defects in the entire production processes, shows that the Insulation process is the process that found the highest defects. This process is the most interesting process that should be monitored. It seems to be a critical process of the production. So this process is selected for the study of this project. The Statistical Process Control (SPC) is applied to monitor the Insulation process to see its characteristic and to see whether it is in control or not.

Analyzing the SPC Control Charts

The control charts and statistics of the defects data show that the insulation process is in control. However, when look carefully at the details we found that there are some points that should be determined further. One obvious point is the difference of defective items, i.e. week 4 has the defective items of only 200 pcs. But week 3 has 293 pcs. To compare these four weeks, a new control chart is constructed. This new chart combines all the data from these four weeks and recalculates the control limits (UCL, LCL. and CL); and new descriptive statistics are formed. The new np-chart for week 4 is shown and follows by its descriptive statistics information.

The analysis result of the four weeks chart shows this is the warning that there may be a shift occurring in this process. So we should try to investigate what factors may cause this shift. The cause-and-effect diagram is constructed to help us consider the probability causes of the defective item that may occur in the process.

For this project study we try to set every factor to the same state, except that the same workers whom we cannot use the same person for the whole study period. In each day, there are two shifts (8 AM to 6 PM and 8 PM to 6 AM). In each shift, there are two workers who work together, and there are totally 12 workers assigned for this section and they will be rotated continuously.

If we assume that others factors (except workers) are in steady state, the problem may be caused by some workers. However, the information that we have may not be enough, due to the limitation of time for this project study, to exactly point out the cause of the problem. But it can show us a warning so that we will closely observe the process to find the real cause of the problem.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

After finishing the study, we can see that the Statistical Process Control (SPC) is very useful for this production process. The control chart can be used to show the characteristics of the process. This is important to see whether the process is in control or not.

The process that is used to apply SPC is the Insulation which is the critical process in the Signal cable production line. We use four weeks to collect the defective data for using in this project.

For this project study, when we construct the chart with a range of one week, all of them show that the processes are in control. But when we combine all four weeks together, we found the process is not so steady. If we did not plot a chart it may be very difficult to see this characteristics trend. So it seems to be better to use the data for longer periods to calculate the control limit, it will make the control chart more accurate. However, the points that go out of the control limit should be excluded for the control limit calculation.

The benefits of using SPC for this study project are:

(1) Keeping the record of the defective items.

(2) Showing the status of the process being observed.

(3) Warning us to closely look at the process if there arc any points

(4) Being a pilot project for other production processes.

The only disadvantage of applying SPC is that we have to spend more workers for this SPC process. However, it is worth the cost of using SPC for the improvement of quality control.

The project also shows that SPC can only show us the signal of nonconforming in the process, it cannot be used to tell what the cause of the defect is. So we should use other Quality Control tools in assistance. Pareto chart is used to see the statistics of the defective types, and cause-and-effect diagram is used to show the possible factors that may cause the defect in the production process.

6.2 Recommendations

To implement SPC technique to the production process for this Signal cable product, the control chart may be calculated from the recorded data. And the control limit should be frequently observed until the process seems steady. If the process is stable, the average value of historical control limit may be used for plotting the control chart without recalculating the control limit for every new recorded data.

SPC technique combined with other Quality Control tools is very suitable for this production process. They will make the inspection process more efficient. These quality control tools should be able to applied to other Signal cable models with almost the same methodology. It is an important step to go further to the total quality control system.

The advantage of SPC is that sampling is done frequently, which increases the chance of finding a process problem in its early stages. Frequent data collection allows production to be stopped as soon as a problem is detected, so that minimum waste is generated. Further savings are enjoyed since value is not added to defective products in subsequent processes. The advantage of using the SPC approach is that it addresses the process rather than the repair aspect of the business. It is a proactive, preventative and innovative approach rather than a reactive and conforming one.

As Deming said "It is good management to reduce the variation of any quality characteristic (say thickness or measure of performance), whether this characteristic be in a state of control or not, and even when few or no defectives are being produced" And Zero defects is not a sufficient aim for continuous process improvement of technical expertise itself which is not good enough and the company should pay attention to training,capital equipment , management philosophy and structure that encourages workers to strive for quality products

The point of making control charts for SPC is to look at variation, seeking special causes and tracking common causes. Special causes can be spotted using several tests:

Types of errors:

Control limits on a control chart are commonly drawn at 3s from the center line because 3-sigma limits are a good balance point between two types of errors:

- Type I or alpha errors occur when a point falls outside the control limits even though no special cause is operating. The result is a witch-hunt for special causes and adjustment of things here and there. The tampering usually distorts a stable process as well as wasting time and energy.
- Type II or beta errors occur when you miss a special cause because the chart isn't sensitive enough to detect it. In this case, you will go along unaware that the problem exists and thus unable to root it out.

All process controls are vulnerable to these two types of errors. The reason that 3-sigma control limits balances the risk of errors is that, for normally distributed data, data points will fall inside 3-sigma limits 99.7% of the time when a process is in control. This makes the witch hunts infrequent but still makes it likely that unusual causes of variation will be detected.

When SPC is successfully implemented, products are produced within specified limits before they reach the end of the process, so the probability of rework is small.

While it is a good practice to conduct an audit of a process or product, it is unnecessary to inspect every item produced because that is redundant and expensive. The quality assurance department should inspect a sample, analyze the statistical process control and keep the process variation under control.

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