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Global transformation

Statistical Process Control (SPC) Basics

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Introduction to SPC

What is SPC?

Let's begin by analyzing the meaning of Statistical Process Control word by word.

- Statistical: Using numbers or data
- Process: A set of conditions that produce a result
- Control: Making something behave the way that we want it to behave

SPC is using numbers to make a set of conditions behave the way that we would like for it to behave in order to obtain the results that we desire.

Always remember that the goal is to continuously improve the results, not just maintain the current condition!

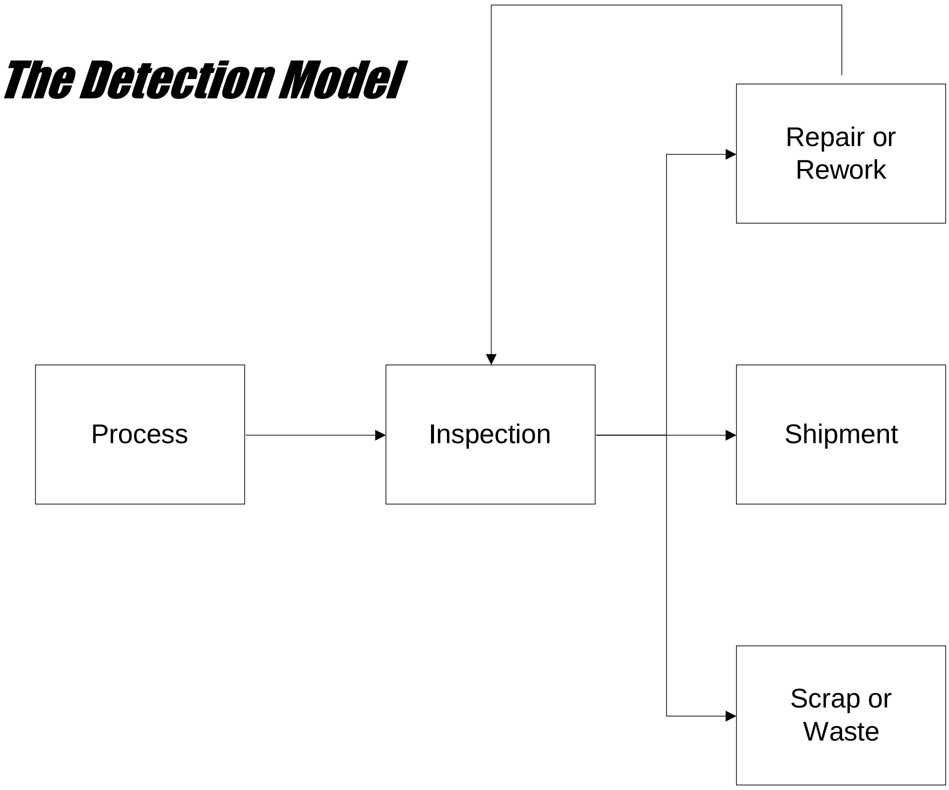
Statistical Process Control (SPC) will reduce or eliminate your need to rely on sorting or inspection! Statistical Process Control will also increase your productivity while reducing your risk of shipping non-conforming products.

The Process is the center of SPC! Understand what the Process is and that the purpose of SPC is to make the Process behave as we want it too. It is critical that any SPC system allow analysis of the Process as well as the Part and Test characteristics. But don't be mislead into thinking that SPC is just for process control. It is much more than that. SPC is about understanding the process behavior in order to get the most from it.

There are many who make SPC much more complicated than it really is. The plain truth is that SPC just measures how your process has performed in the past and uses the information to forecast how it will perform in the future. No crystal ball is needed and you don't have to be a wizard. You don't have to be a statistician either! The fundamental concepts of SPC are easy to understand and apply, so don't be too concerned about the "statistical" area of SPC.

However, be aware that SPC will not magically "fix" all of your problems! SPC isn't a cure all! It is a very powerful tool when properly applied, but creating a control chart isn't going to miraculously fix all of you problems.

Detection and Prevention

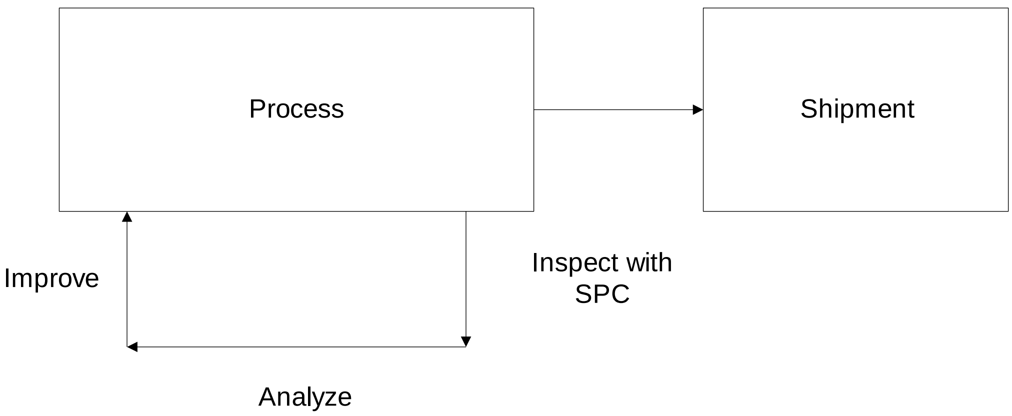


The Detection model relies on inspectors to check the product and sort it into acceptable, rework, or scrap

For many years the term Quality Control meant inspecting to remove non-conforming products. Sorting products is not only very expensive, you are paying one employee to make the product and another to make sure it is right, but it is also not very accurate. Studies have shown that 100% inspection is approximately 80% effective.

Statistical Process Control leads to a system of preventing non-conforming product during the production process instead of waiting until the products are complete. This reduces waste, increases productivity, makes product quality more consistent, and reduces the risk of shipping non-conforming products.

The Prevention Model



The Prevention Model forces the process to improve, eliminating or reducing inspection requirements and waste.

The Origin of Statistical Process Control

Dr. Walter A. Shewhart, a physicist at Bell Labs, is responsible for the application of statistical methods to process control. Dr. Shewhart specialized in the use of statistical methods for analyzing random behavior of small particles. When he was asked to help the Army design a standard radio headset for the troops he naturally applied his knowledge of statistics. He began his design study by measuring the head width of approximately 10,000 troops and creating a frequency distribution of the data.

Dr. Shewhart was surprised that the data resembled what we now call the “bell shaped curve” when plotted. He had seen this normal distribution of data before during his studies of particle movement and now that he saw the same pattern with the head width data he wondered if the same patterns and methods of analyzing them could be applied to other cases. Dr. Shewhart concluded that every process exhibits variation. Some display controlled variation (common cause) and others display uncontrolled variation (assignable cause).

He went on to develop some descriptive statistics to aid manufacturing and authored a book titled, “***Economic Control of Quality of Manufactured Product***”.

One technique described in his book is the Shewhart Control Chart or what we know as the $\bar{x}$ and r chart. The purpose of his Shewhart Control Chart is to present distributions of data over time to allow processes to be improved during production. This chart changes the focus of Quality Control from that of detecting defects after production to one of prevention of defects during production.

Dr. Shewhart defined a process as being controlled when “through the use of past experience, we can predict, at least within limits, how the process may be expected to vary in the future.”

Distributions

A Distribution is a Histogram that presents a graphical analysis of data by plotting the number of times that a measured value occurs. The purpose of the distribution is to gain knowledge about the system. Basic information, such as the central location, the width of the spread, and the shape of the data is shown.

Location, the Measure of central tendency

There are three measures of central tendency; Mean (Average), Median (Mid-point), and Mode (Most frequent).

To estimate the population mean, the arithmetic mean is calculated using the equation,

$$\overline{X} = \frac{\sum x_i}{n}$$

where $\overline{X} =$ arithmetic mean

$\sum =$ sum of

$x_i =$ observed individual data values

$n =$ number of individual data values in the sample

When compared will show how data is grouped around a center and will describe the central position of the data. When a distribution is symmetrical, the mean, mode and median will be equal.

Measures of Dispersion or Spread of the Data

The two basic measures of spread are the Range, the difference between the highest value and the lowest value in the sample, and the Standard Deviation, the variation of the data within a statistical sample. A large range or high standard deviation indicates dissimilar values within the sample set.

To estimate the population standard deviation, the sample standard deviation is calculated using the equation,

$$s = \sqrt{\frac{\sum \left(x_i - \overline{X}\right)^2}{n-1}}$$

where $\overline{X} =$ arithmetic mean

$\sum =$ sum of

$x_i =$ observed individual data values

$n =$ number of individual data values in the sample

Some other measures of the shape of the distribution are:

Skewness, which describes the symmetry of the distribution.

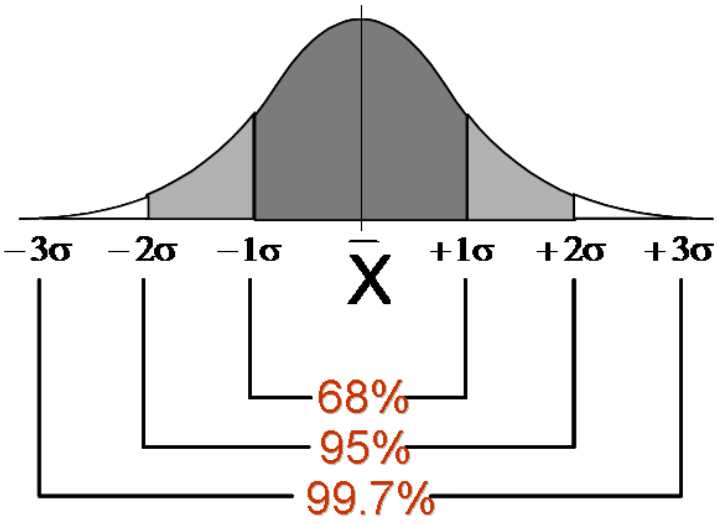
Kurtosis, which describes the peak of the distribution.

A "Normal" Distribution has the following features:

- It is symmetrical about the mean
- The mean, mode & medial are equal
- The curve is bell shaped
- Values concentrated around the mean
- Area under the curve equals 1, 50% of data on left side of mean, 50% on the right
- 99.73% of the values fall within ± 3 standard deviations of the mean

Central Limit Theorem

A group of sample averages tends to be normally distributed. As the sample size increases, the tendency toward normality improves. This allows users to form conclusions about populations based on sample statistics.



Variation

There are two types of process variation; ***common cause variation***, which is the variability of the system itself, and ***assignable cause variation***, which is the variability that comes from outside influences.

The goal of Statistical Process Control is to be able to understand the difference between the two types of variation and react only to the assignable cause variation. Adjusting a process that is "in control" is tampering and increases the variation of the system.

The main points of Variation:

- ***Common cause*** variation is the variation inherent to the system. This variation can only be changed by improving the equipment or changing the work procedures. The operator has little influence on this variation.

- ***Assignable cause*** variation is the variation from sources outside of the system. It can occur due to operator error, use of improper tooling, equipment malfunction, or raw material problems.
- A process is “In Control” when it is showing primarily common cause variation. Being “in control” means that the process is running as well as it can. ***It doesn’t mean that the product is acceptable.*** We have to remember that the system may not be able to make acceptable products. Being “in control” has nothing to do with being able to make “good” products.
- Process adjustments should be made only when characteristics are “out of control”. ***The goal of SPC is to eliminate unnecessary adjustments, not create more changes in a process.*** Making adjustments when the process is in control is called “tampering.” Tampering always increases the variation of the process!

Tampering

When a process is in state of “statistical control,” with primarily common cause variation present, any adjustments made to the process will only increase the variation of the process. Adjusting a process that is in control is referred to as “tampering.”

Populations and Samples

A population consists of all of the possible elements or items associated with a situation while a sample refers to only a portion of the possible elements or items.

As an example, consider that you have the perfect job of being a taster in a pie factory. If a day’s production is one pie, that pie would be the population. Then if you “tasted” the entire pie you would be evaluating the population. You may be satisfied with your work for the day, but management would not be pleased that there is no pie left to sell. Now if you were to slice the pie into twelve sections and take just one of the sections for the test. The evaluation slice will serve as a representative for the entire pie and you still have eleven slices left to sell.

The sample must be representative of the population so as production increases to several pies per day you may be required to sample one slice from each pie. A sample can give a true representation of the population only if it is random and unbiased. Imagine that you always use the same slice location for the pie samples. It may be possible that the location of that slice as the pie moves through the oven allows it to be perfectly cooked while the other side of the pie may be slightly undercooked. A true random sample would be one that is taken from different or random areas of each pie sampled.

Sampling frequency and sampling subgroup size are also critical to a successful sampling plan. The sampling frequency depends on how fast the process is changing. To be representative of the population, the samples must be taken often enough to catch any expected changes in the process. Frequencies are usually defined in measurements of time, such as every thirty minutes, hourly, or daily, but may also be defined in number, such as every other product, or every fifth product. The subgroup size determines the sensitivity of the chart. As the sample size increases, the statistic plotted becomes more sensitive. The process shift to be detected by the chart becomes smaller as the sample size increases making the probability of concluding that the process was out of control when it was not higher.

Review of the main points concerning Populations and Samples:

- The Population consists of all of the elements or items associated with a situation. In our example, when one pie per day was produced, that pie was the population.

- The Sample refers to a portion of the population that is taken to represent the population. In our example, one slice of the pie was the sample.
- Sampling Frequency depends on how quickly the process changes. You should consider items such as employees, raw materials, and equipment when evaluating the sampling frequency.
- Subgroup Size should be one when process adjustments or raw material changes must be made with each part, when only one value represents the condition being monitored (daily yield, past week's overtime), or when sampling from homogeneous batch.
- Subgroup Size should be several parts that can be produced without making any process adjustments and odd sample sizes are recommended because they have a natural "center point" or median.

Rational Sampling and Subgrouping

Rational samples are taken with regard to the way the process is measured, what, where, how and when it is measured. Samples must be taken frequently enough monitor any changes in the process. Samples should be selected with the goal of keeping the process stream intact.

Once the data has been obtained rationally it must be subgrouped rationally. A rational subgroup is one where there is little possibility of having assignable cause variation between samples within the subgroup itself. If only common cause variation exist within the samples, then any differences within or between the subgroups will be attributable to assignable cause variation. We should also remember that sometimes data must be grouped in subgroups of one. To force a subgroup of $n > 1$ in this case would ruin the control chart. Don't be mislead into thinking that more samples in a subgroup is always better.

Process streams should not be mixed in the subgroup. If the subgroup includes output of two or more process streams and each stream can't be identified, the sampling is not rational.

Principles for Subgrouping

Advanced Topics in Statistical Process Control, Donald Wheeler

- Never knowingly subgroup unlike things together.
- Minimize the variation within each subgroup.
- Maximize the opportunity for variation between the subgroups.
- Average across noise, not across signals.
- Treat the chart in accordance with the use of the data.
- Establish standard sampling procedures.

Random and Bias

The purpose of the sample is to accurately represent the population. Statistical formulas that are used to estimate population are based on the premise that the samples are random. A ***Random*** sample is one where every item in the population has an equal chance of being selected.

A sample is ***Bias*** when some of the items in a population have a greater chance of being sampled than others.

5 Ws and 2 Hs of Sampling

- ***Who*** will be collecting the data?
  Evaluate the abilities of the operator collecting the data. How much time does the operator have? Does the operator have adequate resources to collect the data?

- ***What*** is to be measured?
  Focus on Key Characteristics. Always remember that it cost money to sample! We should focus on the characteristics that are critical to controlling the process.

- ***Where*** or at what point in the process will the sample be taken?
  The sample should be taken at a point in the process that allows the data to be used for process control.

- ***When*** will the process be sampled?
  Samples must be taken often enough to reflect shifts in the process. A good rule of thumb is that two subgroups are taken between process shifts.

- ***Why*** is this sample being taken?
  Will the data be used for Product control or Process control?

- ***How*** will the data be collected?
  Will samples be measured or evaluated by hand or will the data be retrieved from an automated measurement source?

- ***How many*** samples will be taken?
  The sample quantity should be adequate for control without being too large and creating control limits that are “too sensitive”.

Process Behavior (Control) Charts

Introduction to Control Charts

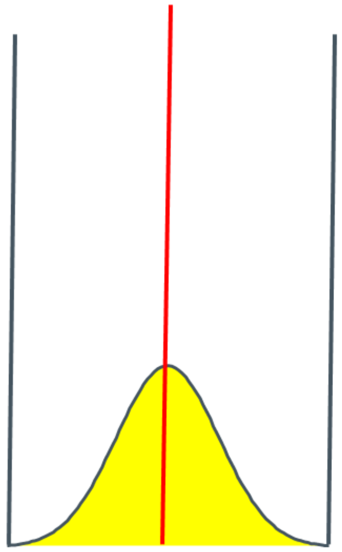
Process Behavior (Control) charts are basically tools used to determine if a process is stable or unstable. The terms “in control” and “out of control” are typically used when referring to a stable or unstable process. A process is in control or stable when the average and standard deviation are known and are predictable. Therefore a process is out of control or unstable when either the average or standard deviation is changing or unpredictable.

- In Control – Stable, predictable, consistent, unchanging
- Out of Control – Unstable, unpredictable, inconsistent, changing

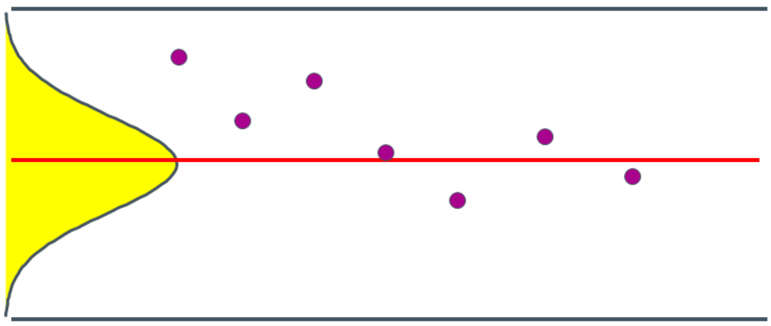
All control charts have three common elements.

- **Plot points** – They usually represent individual measurements, averages, standard deviations, or ranges.
- **Centerline** – Usually, though not always, the centerline is the average of the points plotted on the chart.
- **Control limits** – These represent the amount of variability in the process.

Control limits are typically set to ± 3 standard deviations from the average. For variables data, two control charts are used to evaluate the characteristic: one chart to show the stability of the process average and another to describe the stability of the variation of individual data values.



The Control Chart is derived by taking a Distribution, which defines the Centerline and Limits and rotating it so that data can be added. Data or Plot points are recorded in time series to present a view of the process Average and Variation over time.



The Four Foundations of Shewhart's Charts

Foundation One

Shewhart's charts **always** use control limits which are set at a distance of three sigma units on either side of the central line.

The three-sigma limits are always based on data. The define when action should be taken on the process. ***Control limits are never based on any calculation using the specification limits.*** Specification limits are the customer requirements and define how to treat the product, not the process.

Foundation Two

One must always use an average dispersion statistic or a median dispersion statistic when computing three-sigma control limits.

Using the average or median of several dispersion statistics increase the "robustness" of the chart.

Foundation Three

The conceptual foundation of Shewhart's charts is the notion of rational sampling and subgrouping.

Foundation Four

Control charts are effective only to the extent that the organization can use, in an effective manner, the knowledge gained.

Any knowledge is only as effective as our ability to take action on it.

More on "Control"

In SPC we hear the word "control" interchanged with "stable." When we say a process is "in control," we are really simply saying that the process is stable. Always remember that "in control" does not mean that the process is within specification. A process may be very stable while consistently making bad product!

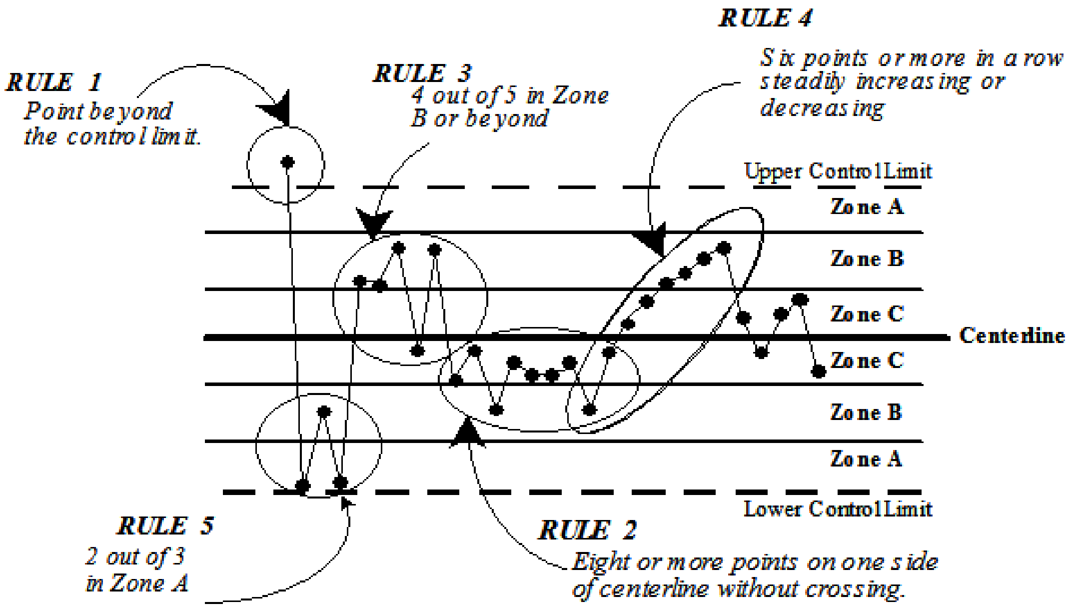
When a process is in control there are many benefits:

- Scrap and rework estimates may be made prior to production.
- Machine settings can be adjusted to optimize throughput.
- Engineers can incorporate statistical tolerance setting into their drawings. This will increase component tolerances without compromising assembly performance.
- Product designs can be statistically modeled to accurately predict fit and performance yields prior to prototype assembly.
- Machine utilization can be optimized. For example, high precision machines and resources will not be wasted on manufacturing low-precision dimensions.
- Process improvement resources will be better spent.

While a lot is gained from processes in-control, many processes are not stable or predictable and are out of control.

A process is usually judged to be out of control based on the following five rules. These rules signal a change in either the process average or the variation.

- Rule 1: Points beyond the control limits
- Rule 2: Eight or more consecutive points either above or below the centerline
- Rule 3: Four out of five consecutive points in or beyond the 2 sigma zone (referred to as *zone B* in the graphic).
- Rule 4: Six points or more in a row steadily increasing or decreasing
- Rule 5: Two out of three consecutive points in the 3 sigma region (referred to as *zone A* in the graphic).



A process that is out of control also reveals much useful information.

- Detect unwanted process changes.
- Detect desirable process changes.
- Prove that a process change was or was not an improvement.
- Determine when to make a change in a process.
- Verify measurement system improvements.

Specification Limits and Control Limits

Specification Limits are boundaries set by the customer, engineering or management to designate where the system must operate. Specification limits are also referred to as the "Voice of The Customer" because they represent the results that the customer requires. If a product is out of specification it is non-conforming and not acceptable to the customer.

Control limits are calculated from the process itself. Since control limits show how the process is performing, they are also referred to as the "Voice of The Process." They show the variation within the system or the range of the product created by the process. If a product is out of the control limits, it just means that the process has changed and nothing else. The product may be in or out of specification.

The main points on Specifications and Control Limits:

Specification limits are boundaries set by the customer, engineering or management to designate where a system must operate. Specification Limits are called "The Voice of the Customer" because they represent the results that the customer expects. Always remember that a customer may be the next department or process within your production system.

Control Limits are calculated from the process itself. Since control limits show how the process is performing, they are also referred to as the "Voice of The Process." Since control limits show how the process is actually performing, they have no relationship to the specification limits. The process may be "in control" or within its control limits and still be out of the specification limits. If a process is "out of control" it means that the process has shifted. The shift could be from a decrease or increase in variation, but either way it has nothing to do with the specification limits.

Control limits must never be calculated from Specification limits!

Capability

Capability is a prediction of future performance

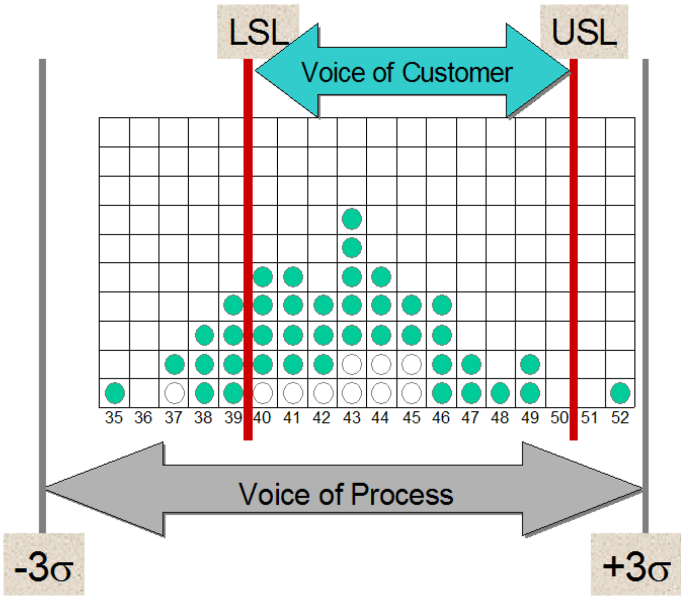
A process should be "in control" before the capability is assessed. "In control" means that the process is showing primarily common cause variation. It is therefore stable and predictable. Remember that being "in control" should not be confused with "being good." A process may be "in control," stable and predictable and still be outside of the product specification limits.

A process must have been in control in the past, to enable us to use the data to predict the future!

Hearing Two Voices

The "Voice of the Process" is represented by the 6 sigma range of the distribution. Again, remember this shows ONLY the capability of the process itself. There is no comparison to customer expectation or the specification limits.

The "Voice of the Customer" is the specification limit range. Remember, this represents ONLY what the customer expects.



The two primary capability measures are:

Cp and Cpk

Cp shows how well the 6 s range fits into the specification range. Not where the process is actually producing!

It is the Voice of the Customer divided by the Voice of the Process using the equation,

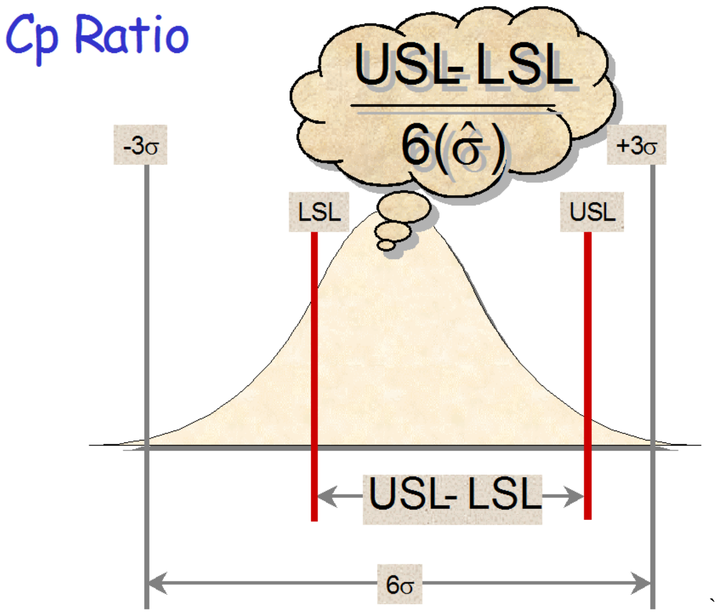
$$\frac{USL - LSL}{6\hat{\sigma}}$$

where $USL - LSL =$ The Upper Specification Limit – Lower Specification Limit

$6\hat{\sigma} =$ Six (6) times the Estimated Process Standard Deviation

For example: a Cp of 1 would mean that the Customer's voice and the Process voice are the same. The process would be said to be "capable" of meeting the customer's criteria.

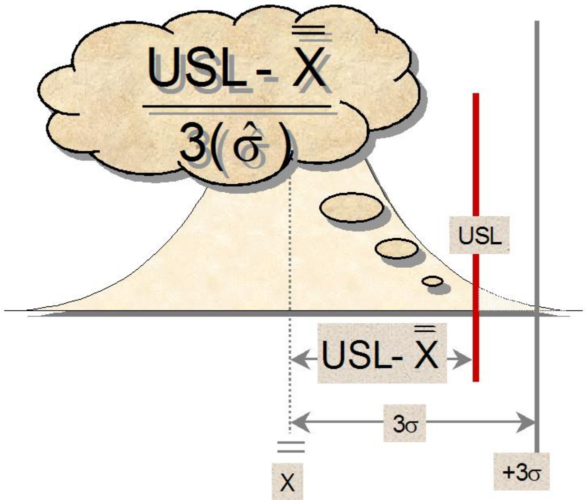
Remember that Cp shows the optimum capability of a process! Just what the process is capable of!



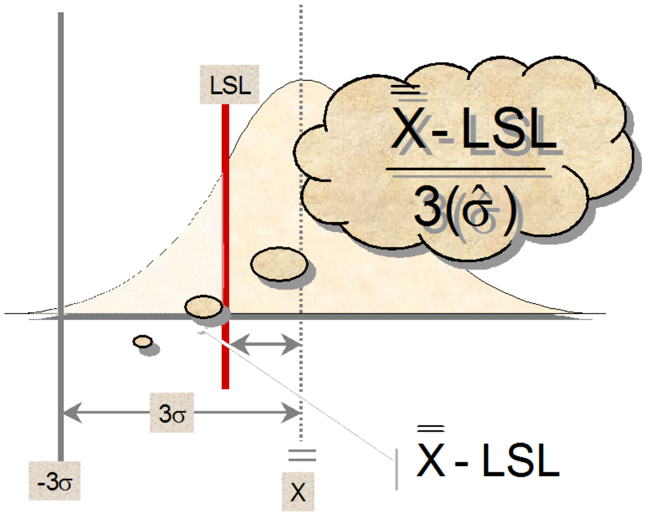
Cpk shows the relationship of the 6 sigma spread to the specification limits.

This is done by comparing the average of the data to the specification limit. The Cpk represents the lowest value of the capability against the upper or the lower specification.

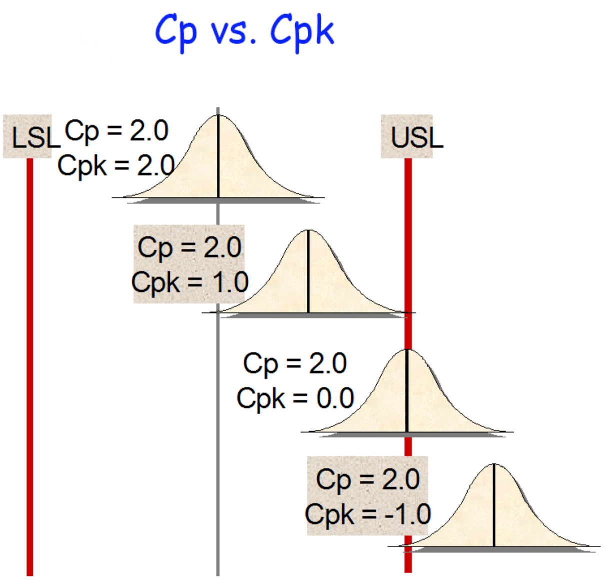
Cpk_{upper} Ratio



Cpk_{lower} Ratio



The Cpk shows where the process is producing, NOT what it's optimum capability is. If you need to know if the process is capable, the Cp must be used.*



NOTE: By no means should numerical summaries of capability be interpreted without looking at a histogram of the data plotted against specification limits. Capability studies should include analysis of control charts, histograms of individual data and capability indices.

Attributes

We have been discussing the benefits of **Variable** data, but there are many situations where there is no measurement value, only a Pass/Fail rating or a number of nonconformance.

Attribute data, pass/fail, ratings, or a nonconformance quantity may also be plotted on control charts and can be critical to process control.

Defects

Defects data, also known as counts data, is used to describe data collection situations where the number of occurrences within a given unit is counted. An occurrence may be a defect, observation, or an event. A *unit* is an opportunity region to find defects, sometimes called the area of opportunity. A unit may be a batch of parts, a given surface area or distance, a window of time, or any domain of observation.

For example, a plastic bottle may contain a variety of Defects, such as burrs, blemishes, or bubbles. These defects may or may not make the bottle a reject, however they should all be accounted for to ensure that process improvements may be made.

Defectives

Defectives data, also known as "go/no go" or "pass/fail" data, are used to describe data collection situations where the unit either conforms or does not conform.

Think SPC!

Statistical Process Control is much more than a group of tools that can be applied to control processes. It goes beyond simply insuring that products are produced within specification or as a "process monitoring" tool. SPC is really about continuous improvement of processes. If SPC is used for reporting data or monitoring, it's real power is never tapped. Learn the tools of SPC without learning to "think SPC" and you simply have some nice tools that can probably be used to satisfy your auditors. Learn the tools and learn to "think SPC" and you will see process improvements, happier employees, increased productivity and increased income.

Thinking SPC first involves a commitment that upper management wants to improve processes and truly reap the benefits of a Statistical Process Control system. If management only wants wallpaper to make the office look nice and to impress the customers, that is exactly what they will get!

Dr. Deming's first principle stated, "The central problem in lack of quality is the failure of management to understand variation." The first step in management commitment is ensuring that all levels understand variation. Only after management has an understanding of variation will it succeed with Dr. Deming's second principle, "It is management's responsibility to know whether the problems are in the system or in the behavior of the people."

We have to remember that putting out fires is NOT an improvement. Finding an out of control point on a control chart, finding the assignable cause and removing it is NOT an improvement. It is certainly very important to take action on assignable causes to maintain a consistent process, but it is not an improvement. Remember the old saying, **"If we keep doing what we are doing, we will keep getting what we are getting!"** SPC is only fully utilized when the process is improved and the variation is reduced. We must learn to move beyond "process monitoring" and into the area of "process improvement." Imagine how resources could be put to better use if your firefighting time was significantly reduced!

When management learns to "think" SPC, there is a clear understanding of what is required to successfully implement an SPC program.

Reasons that SPC Initiatives Fail and Ways to Overcome Them

1) *We're Special!*
   Management, and / or others in the company feel that their circumstances are so unique or different that SPC is not applicable. Therefore it would be a waste of time and money to even consider it.

   These feelings may occur from numerous reasons, such as:

   - Short Runs (frequent process and / or product changes)
   - Lack of Metrics
   - Fear of change
   - Thinking of their process as an Art Form

   Overcoming the "We're Special" Obstacle

   Explain that if there is a process creating output, then SPC can be applied. The first step is to start collecting data to show how the process behaves. After metrics are defined, data collected and plotted, it is easy to see that the process does have measurable characteristics.

Educating employees in Short Run process control methods is a great way to show them that they are not alone. While we all like to feel special, the truth is that most companies that feel that they are so special that SPC doesn't apply, can benefit the most from it!

2) *SPC Will Fix It!*
SPC isn't a "cure all." If the charts are not utilized, implementing SPC and producing control charts will do nothing more than give you some nice wallpaper. Don't be mislead by thinking that loading an SPC software package and making pretty charts is going to improve anything on its own! Making a control chart can't eliminate variation and it won't solve all of your quality problems. SPC is the foundation of a process improvement methodology, but there are numerous other tools in the QC toolbox that should be used.

The "SPC Will Fix It!" management team will abandon the SPC initiative when it doesn't miraculously solve every problem!

Overcoming the "SPC Will Fix It!" Obstacle

SPC education must include what SPC does. That SPC brings to light Common Cause and Special Cause variation, but other tools are needed to reduce or eliminate the variation.

Train employees to use other process improvement tools to help reduce the common cause variation. Create Corrective Action or Process Improvement teams to work on projects.

3) *Misunderstanding Control Limits and Specification Limits*
There are many instances, before SPC implementation, where product data is collected and compared to Specification Limits. As long as the product is within the boundaries set by the customer we assume that the process is performing fine. The reality is that this is "Product Control" not "Process Control". We are just verifying that the products that we made are within specification and will be acceptable to our customers. When SPC is implemented we then use Control Limits based on the process behavior. However, there is a tendency to keep Specification Limits on control charts even though they should never be there!

Another common problem with SPC initiatives occurs when control limits are based on anything other that the true process variation or when control limits are set to a standard other than ± 3 sigma. If the control limits do not accurately represent the process they are useless and cause more harm than good.

Overcoming Limit Misunderstandings

Train to ensure that employees understand that control limits are the "Voice of the Process". They should how the process is performing. Specification limits are the "Voice of the Customer" and are independent of how the process is actually performing.

Whenever specification limits and control limits are shown on a control chart the operators will be confused. Which set of limits should they use?

If you are using X-Bar charts and show both specification limits and control limits brace yourself for more problems! Specification limits are based on individuals while the X-bar is based on averages. You may easily have an average within the specification limits while individuals are out of specification!

Control charts **always** use control limits which are set at a distance of three sigma units on either side of the central line.

The three-sigma limits are always based on data. They define when action should be taken on the process.

Control limits are never based on any calculation using the specification limits. Specification limits are the customer requirements and define how to treat the product, not the process

4) *Tampering, Tinkering, and Tweaking!*
When a process is in state of "statistical control", with primarily common cause variation present, any adjustments made to the process will only increase the variation of the process. Adjusting a process that is in control is referred to as "tampering." It is very common for an operator to "adjust" a machine that doesn't need adjustment. The natural tendency of a good operator is to tinker with the process to try and make it perform at its best. What they don't realize is that their efforts to improve actually increase the variation of the process.
Management can aggravate tampering by insisting that operators make adjustments when data isn't exactly where they want it. They don't realize that these knee jerk reactions create uncontrollable gyrations in the process. When the process deteriorates, management blames the operator again. The distrust and morale damage that result from this will not only ruin an SPC initiative, but may do irreversible harm to employee/management relations.

Overcoming "Tampering, Tinkering, and Tweaking"

ALL employees, especially management, must have an understanding of variation. Understand that one of the underlying assumptions of a control chart is that each data point is independent of the previous one. The process must be allowed to operate in its natural state in order for us to understand the common cause variation. Training must include how tampering creates bias and nullifies the control chart.

5) Management Responsibility

SPC is not something that employees be expected to implement on their own. Failure to provide the appropriate training and resources will undoubtedly cause the initiative to fail. It is common for management to try to save money by scrimping on training, but the money saved will cost much more eventually.

In some cases, employees get adequate training, but supervisors and management are not trained and do not support the initiative. If management is not comfortable with the SPC concepts they will either stay away because they are uneasy with the changes or they will recommend process changes based on their understanding of the process. Either way, the SPC initiative will suffer.

Overcoming Management Responsibility Issues

Management must provide the necessary resources. Training should be thorough and it must be repeated at regular intervals. Employees change positions and even the best companies have turnover. New employees must be trained and experienced employees must have refresher courses.

Management must be involved with the SPC initiative. For any initiative to be successful it employees must know that management believes in it and understands it. If management merely ask for "pretty charts" that's exactly what they will get!

Management must set realistic goals for process improvement and base their analysis on solid metrics. Management should also involve front-line management in the selection of which areas to apply SPC. If the front-line is involved in the implementation process they will take ownership of the system and help it to gain acceptance with employees.

Management must have SPC training! Managers and front line supervisors must understand what SPC is, what SPC does, and how SPC works! They must understand how decision making will change once SPC is implemented. The bottom line is that if management doesn't commit to the SPC initiative then the employees can't be expected to commit to it!

Remember Shewhart's Fourth Foundation of Control Charts!

Control charts are effective only to the extent that the organization can use, in an effective manner, the knowledge gained. Management must empower the employees and allow them to make decisions gained from the SPC data.

Any knowledge is only as effective as our ability to take action on it.

6) *Measurement Systems and Data Integrity*
Data the lacks integrity has a devastating effect on analysis and decision making. Using "bad" data may be worse than having no data at all.
There are many ways that data may be biased. Operators may be "rounding off" values before the data is recorded, the subgroup may not be rational, the measuring instrument may not be suited for the task, the measuring instrument may be damaged or the measuring instrument may not be in calibration.

Example #1:

Your bagel company is having a problem with customer complaints for bagels that are not completely cooked. Evaluating the SPC system you find that the line inspector samples one bagel from each production oven every 30 minutes. The bagels are cut open and inspected to make sure they are cooked properly. At first you can't understand how the "raw" bagels were shipped, but as you observe the operator you realize that they are always sampling from the outer section of the oven conveyor. Sampling the bagels from across the conveyor may give a more accurate picture of how the oven is performing.

Example #2:

You are measuring plastic bottle caps with a caliper. Five bottle caps are measured to create one subgroup. The caliper displays values to one hundredth of an inch. The caps are very consistent at the hundredth of an inch range, but do have variation at the thousandth of an inch range. Since the calipers do not have enough significant digits to show the variation, your range is based on data taken at the hundredth of an inch range. Control limits calculated off of this range will be unrealistically tight. Any change of the average causes a subgroup to be "out of control." You know that the caps are well within specification and that the control limits are not realistic. You conclude that SPC doesn't work for you and the initiative is stopped.

Overcoming Measurement Systems and Data Integrity Issues

Before the SPC initiative, set rules for data collection and analysis. Criteria should include the least number of significant digits for the measurement system, how much error (including R&R, Bias, and Linearity) is acceptable, calibration frequency for measurement instruments, rules for determination of outliers and what actions are to be taken with outliers.

Sampling practices must be evaluated to prove rationality and the sampling frequency must be sufficient to detect shifts in the process.

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