CUSTOMER MANUFACTURING GROUP

PROCESS IMPROVEMENT TOOLS

CONTROL CHARTS

There are many process improvement tools available to help companies manage and improve their business processes. New ones are created regularly and many are adapted or modified. Quality guru Ichiro Ishikawa taught that 90% of all business process problems can be solved with the Seven Tools of Quality. We concur. In addition, if you could actually solve 90% of your business process problems, you'd be a lot further ahead than you are today. This paper addresses one of those tools, Control Charts

To use Control Charts effectively, you must decide how much variation is acceptable in the process of interest.

By charting variations in the process over time you can determine if your process is in control or not.

Whether or not you think of your procedures as processes in actual practice, they are processes. They may be undocumented and informal (in which case they may be somehow interrelated events that just happen), or they may be formally documented and practiced. The former will often result in chaos and poorly understood performance, while the latter is what a manageable process is; *A documented procedure that defines and orders a set of inputs, activities and outputs, to which we add . . . and sets standards for repeatable performance to accomplish a set of specific objectives.*[1]

The last part of this definition is what leads to the measurement of process variation, for example, just how far above and below a performance standard is a process actually producing. The purpose of a Control Chart is to measure the degree of process performance variation. Measuring a process is a start, the capability to control it is the next step.

Control Charts are used to provide a visual indication of variance in a process. All processes have variances. The question is how much variance is acceptable. The 6-Sigma folks use that metric as their guideline, but many processes need a much lower variation (if airplanes landed safely only at a 6-Sigma rate, nobody would fly), and some can allow more variation. Though sometimes we accept too much variation based on an assumption that better control is either not possible or too expensive.

Japanese car manufacturers created cars with much tighter tolerances than their U.S. counterparts and actually saved money in the process. To use Control Charts effectively, you must decide how much variation is acceptable in the

[1] For clarity, documented processes need to be sufficiently flexible to produce the required output within the environment they operate. Many Marketing/Sales environments are necessarily dynamic. Useful processes in the environment must be flexible. However, adding flexibility that is unnecessary can produce outputs with unacceptable variations . . . unnecessarily.

process of interest. That sets your upper and lower control limits. By charting variations in the process over time you can determine if your process is in control or not. If not, then the key is, are the variations due to common causes, which are inherent in the process, and if they produce unacceptable performance require a process redesign; or special causes, which must be eliminated to keep the process under control.

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Charting What?

Control Charts can be the most mathematically demanding of the seven major process improvement measurement tools. However, they don't have to be as rigorous as their full capability requires. We'll explain.

With all process improvement measurement tools, it is vital that you begin your measurement program with a very definite and clear view of your objective? That is, first know what you need to measure in order to create a new process or improve upon an existing one. What is your objective? Why, and how do you initially think it can be best achieved? Do not embark on a measurement program without at least a starting view of what you want to achieve, and what activities you'll need to measure in order to obtain or improve upon a manageable measure of performance.

We stated above that control charts are used to measure, control and tighten process performance variance. This explicitly requires that you already have an active process in-place that is in daily — or at least frequent — operation; you can't measure process variance without a running process. If you say, "well duh," you'd be surprised at the large number of companies who jumped all over the "Six Sigma" process measurement methodology before soon realizing they first needed an active documented process with designated activity performances that could be measured and which could then be rolled-up to a total (beginning-to-end) map.

As far as Control Charts are concerned, you're off to a good start if you're already measuring process performance in some way. Any quantitative regimen will help you to think critically and objectively; a bad — or good — performing process may not be performing the way you think it is; let the data tell you.

When a Control Chart Can be Particularly Useful

There are a number of process management tools available (we have found seven that have the most value in Marketing/Sales process improvement: Cause & Effect Diagram, Histogram, Check Sheet, Pareto Chart, Flow Chart, Scatter Diagram, and Control Chart), and quite often they can be used in combinations of two or more with greater benefit than a single type alone. Several of these

Some events or activities happen with some frequent and repeatable regularity every hour or day, or whatever.

Other events or happenings are not reflective of your routine or normal operations.

may provide the same useful data and in varying degrees of detail; just consider how fine you want to slice the data collection and how the analysis will be used.

Because Control Charts can be very detailed — and complex in both data collection and analysis — but they don't have to be — consider the following potential applications of a Control Chart:

- Determine if a process is stable or out of control
- Control on-going processes in order to spot and resolve problems in near real-time
- Predict ranges of process performance
- Separate process performance and analysis by both common cause and special cause situations (a bit more on this below)
- Determine if process variation can be better controlled by examining the overall process or by looking at individual component variables, or both
- Complex and sophisticated processes require a great deal more finite data collection and analysis in order to identify and resolve process variations

What You Need to Look At

Before trying to determine what to measure and with what frequency (and then how to calculate process performance variances) for your Control Chart(s), you need to identify and consider the basic types of data you'll be looking at before you can start running mathematical algorithms for them. Very simply stated, there are four basic types of data you may need to collect before you can determine the best-fit Control Chart type to use:

Variable data: This is data that can be measured on some continuous scale such as, for example, time periods, work cell or department activity levels, staffing levels, etc. Here you need to determine sample sizes for each element.

Attribute data: This is data that can be counted as discrete (single, not combinatory) activities or occurrences, for example in-coming sales calls, order placement errors, dropped calls, no call-backs, etc.

Attribute data can be further categorized into (*defect* data) — a discrete activity in the overall flow that is failing to meet your acceptable performance levels), and (*defective* data) — an entire unit of "production" that fails to meet your desired performance level; for example, in-coming sales inquiries that aren't converted to orders from first response to the dropped opportunity.

Collection rates must be determined for each and all of the critical through-put activities, measurement frequency and time-of-day (or whatever is a key variable; this may be one of the items that will point to further analysis).

In preparing for and measuring various aspects of marketing and sales systems performance, do not allow the vagaries of your market and customers to be excluded in the measurements of your system's performance.

Inability to understand the data is non-actionable information.

Common Cause vs. Special Cause

Some events or activities happen with some frequent and repeatable regularity, every hour or day, or whatever. Although the magnitude or amplitude and frequency may vary within a definable period of time, they are normal occurrences and fit a pattern of routine activities. In simple terms these are called "common cause" events or occurrences. Although the data points may bounce around they reflect your standard operating conditions or environment; things that happen within your normal — or *internal* — system.

Other events or happenings are not reflective of your routine or normal operations; these are called "special cause" events. W. Edwards Deming (made famous for his process improvement methods in Japan after World War II) defined a special cause as "an unusual event *external* to the system."

One way to consider the difference here is to think of common cause as system-related (process, procedures, practices, etc.), with special cause as external to the system that cause problems and faults that do not represent the norm.

The cautionary note here is to not mix the two in your measurements since melding the special in with the common will skew your data collection, findings, and analysis in ways that will make it impossible to relate the *system's* performance to its true cause-and-effect results. You may wish to measure both categories of cause, but do it separately. If the external perturbations begin to drift into a more normal pattern of events (that is, the exceptions start to look like the rule), it is safe to say that you have a process that is out of control, or in the least, influences that you may have thought were external to the system may in fact be internal if the system is viewed from a broader perspective or higher altitude.[2]

In preparing for and measuring various aspects of marketing and sales systems performance, do not allow the vagaries of your market and customers to be excluded in the measurements of your system's performance. The data collection and analysis and mining of your CRM system may be technically spot-on, but the goal should be to improve your value to your customer and not to improve the access to and speed of your software.

If you think all or most of the exigencies and vagaries of your customers are a special cause — external to your system — then you're right in line for a top position in

[2] In Marketing/Sales processes there are obviously lots of special causes because the customer is external to the system. However, don't be too quick to assume that all of these vagaries are really special causes. You may find that you are influencing this behavior more than you think. Many companies run specials at month-end or quarter-end, resulting in a skewed order pattern. One might decide this is a special cause variation in order rate, when in fact, you have trained the customer to buy when you offer specials.

the U.S. airline industry. These folks can slice and dice butts-in-seats numbers a hundred different ways while their market disappears. Special cause indeed!

Don't "cherry pick" the data in order to demonstrate only the good events or to highlight only the unacceptable variances.

Charts *You* Can Understand

A number of different types of 'Control Charts' are available, and your selection of which one to begin with should be based on the type and detail of your information needs, your ability to not only understand the data presented and to know how to collect it, and your ability to apply the data. That is, transform data into actionable information.

Unless you're an accomplished statistician and absolutely love (esoteric) number crunching, we recommend that you begin your Control Chart familiarization with the easiest to understand type, called the 'X and Moving Range Control Chart' which is highly suitable for handling attribute data.

A sidebar on control chart history. In the 1920's Walter Shewhart of Bell Laboratories developed a theory that there are two components to process variation: a steady component from random variation, and intermittent variation due to assignable causes.[3] Shewhart's improvement approach was that assignable causes could be removed with an effective diagnostic program, while random causes could not be removed without making basic process changes.[4]

Other types of Control Charts require an understanding of probability distribution theory and specific control limit calculation formulas. That is, go back and take that course in statistics you either avoided or flunked. These other types are (and we'll leave you to your own research here):

- X-Bar and S chart
- Median X and R Chart
- c chart
- u Chart
- p Chart
- np Chart
- s Chart
- s** Chart
- There are still others, for just one example: EWMA — Exponentially weighted moving average of quality characteristic measurement within one subgroup. Get the picture?

[3] Walter A. Shewhart, *Economic Control of Quality Manufactured Product,* ASQ Quality Press, 1931, reprinted in 1980. Shewhart's ideas are similar to Deming's common cause and special cause concepts discussed previously.

[4] Forest Breyfogle, Control Charting at the 30,000-foot-Level, Quality Progress, November, 2003.

Remember that the purpose of any tool is to help you make better decisions. Adding complexity which does not result in better information to make better decisions is waste.

Although the math gets increasingly complicated here and there are various tools available to help you through the maze, our cautionary note here is to be at least familiar with your *data collection methodology* and the *calculation algorithms.*

Management of the Analysis

Before diving a bit deeper here, we'll point out three of the most crucial management analysis tips (the software tools can't do your decision-making, well, not all of it at any rate).

Use all the data that the collection system can provide for the standard process system, practice, procedure, etc. That is, don't "cherry pick" the data in order to demonstrate only the good events or to highlight only the unacceptable variances; both — and the more normal points in between — are part of the system as a whole. Making the good look better and bad look worse will absolutely not help you to remove process variances and improve total process performance.

- A process that appears to be stable or in-control doesn't mean that it is getting the job done — its management objective — in the way that is needed; somewhat akin to "the operation was a success but the patient died." For example, if your CRM system is doing a seemingly excellent job at identifying sales opportunities and providing acceptable numbers of qualified leads, but you're losing orders to your competitors, you have an overall process problem even if the software is operating flawlessly.
- Although data that can be presented on a Control Chart can get pretty hairy with lots of data points and statistical notes, there are a few eyeball-at-a-glance patterns that may be easily seen as an aid to knowing where to dig deeper. These have to do with such "keys" as:
    - One or more data points falling outside the control limits (usually based on the number of standard deviations above or below the average)
    - A number of points (usually 6 or more in a row) that are gradually increasing or decreasing
    - Six or eight points in a row that are on one side or the other of the centerline
    - A string of points (usually fourteen) that are alternating up and down, usually within one or two standard deviations, and although within the control limit, indicate some variables that need to be examined. These may indicate a "surprise" in the making
    - There are many others, and based on the specifics of your measurement program, you'll want to learn-as-you-go by doing your own research on

the subject (lots of experts have their own "tricks" to facilitate the spotting of significant process performance variances). The key here is to spot these variances before the process goes into collapse

Remember, the emphatic management resposibility here is not the collection and crunching of data but instead the synthesis of actionable information and then taking action on it.

Doing the Crunching

Now is where the more involved math comes into play, such as, averages, ranges, means, standard deviations, etc. for each of measured elements. Center lines for each of these need to be plotted on a graph (there are prescribed calculations for this), and then — this next becomes the core calculations at the heart of most Control Charts — calculating the upper and lower control limits for the attribute data. These levels serve to establish the range above and below the center lines within which the process may be considered to be within acceptable levels, and outside of which process *variances* can be seen. Remember, we previously said that the purpose of a Control Chart is to determine a variance in a process, which is an unacceptably high or questionably low defect rates. Wide and frequent variations from a center line between the upper and lower control limits will usually indicate an unstable process (that is, out of control) at the least.

As long as you don't drive yourself beyond your measurement and calculation acumen, there are published tables that can help you determine necessary sample sizes and their corresponding constants for averages, ranges, and the like. A plethora of process Control Chart *software* is available (Google provided 217,000 items of meaningful-to-meaningless listings), some of which will run in Excel and/or will process your Excel data and do all the calculations for you — or you can hire an expert to do all the crunching, etc.

Although the math gets increasingly complicated here, and there are various tools available to help you through the maze, our cautionary note is to be at least familiar with your *data collection methodology* and the *calculation algorithms*. All too often *these* can be the cause of reported process variances in which the protocols being used do not match the characteristics of the actual process and process activities.

Don't get carried away by the math and accept things as they appear; put a human in the loop who understands the process(es) under measurement and can see that "something doesn't look right here" before you begin the analysis and interpretation phase. Again, the entire data collection methodology (what, how, when, and sometimes by whom) may need some tuning. Although the calculus may be correct, the data may not accurately reflect the process of interest.

Finally, someone (perhaps you?) must analyze what all of this means in order to determine what corrective actions must be taken in order to improve the performance of the process that is being measured. Remember, the emphatic management responsibility here is not the collection and crunching of data but instead the synthesis of actionable information and then doing something about it.

Look for common and special causes for poorly performing processes. With Control Charts you may be able to dig down to the lowest fault producing elements. Once you begin to identify the ill-performing process elements and activities, you may want to use Cause & Effect (also called Fishbone or Ishikawa) diagrams to bring the most knowledgeable people together to start lending human expertise to the identified process deviations.

There are many further control chart refinements that you will not need initially — or perhaps ever — and we'll leave it up to you to continue your knowledge advancement.

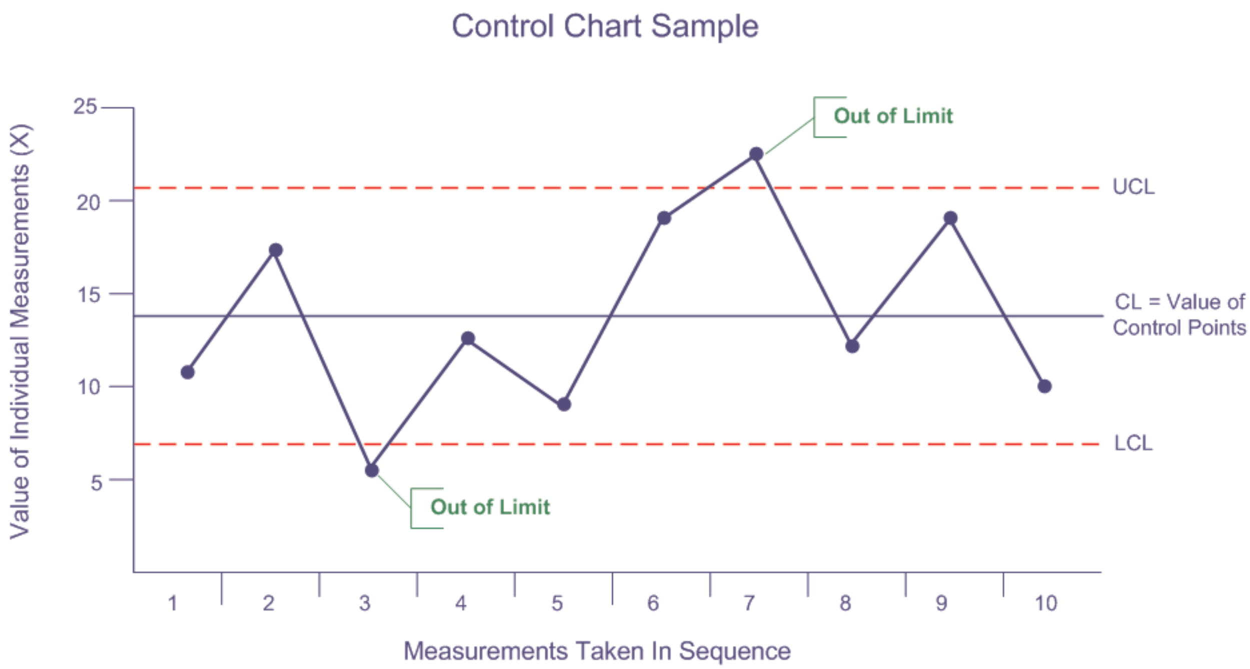
At the risk of being redundant and trite, we again remind you in this article — as we have in all of this series of Process Improvement Tools — of the following process management point before you start collecting data willy-nilly: Know what you need to measure and how to measure, and then analyze it in order to accomplish a targeted process performance objective. The facts can indeed help you if you've obtained the right ones in the correct way.

A second-to-final thought. If a wide-ranging process improvement measurement program is being considered, first familiarize yourself with all the tools that are available and how they might be used in your environment. Inappropriate tool selection can lead to frustration and loss of credibility with the entire program. And, if you don't personally have the time to plan, manage, execute and oversee the program, you may want to consider designating a competent and inquisitive person (or hiring one) to be responsible for it. We emphasize the "inquisitive" nature here and by this we mean an individual who will say on her/his own, "I wonder if . . .," or, "Hmm, this looks interesting — or not what I expected."

And now, the final (well, probably not, but all that we'll do here) suggestion. It has been our experience that before you turn on the measurement switch, you will reap dividends many times over if the process improvement person-in-charge actually observes each process that will be evaluated. That is, have at least a general familiarity (if not indeed at a working level) of the what, who, when, and how of the overall process flow. The benefits here will be process and people knowledge, and both will be crucial to your success.

Control Chart Examples

The following very simplified sample control chart depicts a hypothetical process measurement of data point values (the Y — or vertical line) over a stipulated number of measurements (the X — or horizontal line) in a desired time period.



'CL' is the Center Line and is the statistically calculated median value of the data points (this could also be the mean value)

'UCL' is the Upper Control Limit of these values: the calculated limit above the mean line. Shewhart found in practice it should be placed 3 standard deviations above the mean. For him it was not a customer- or quality management- determined spec; it was the 'voice' of the process, that is, it was what the process was revealing about itself.

All of that math notwithstanding, you must remember that the only thing that really matters is meeting customer needs with minimal waste. Control limits should be set to assure that you meet your customers needs, wants and demands and that waste is minimized. Six Sigma (+/-3 standard deviations) may be too tight or too loose of a control limit depending on the situation.

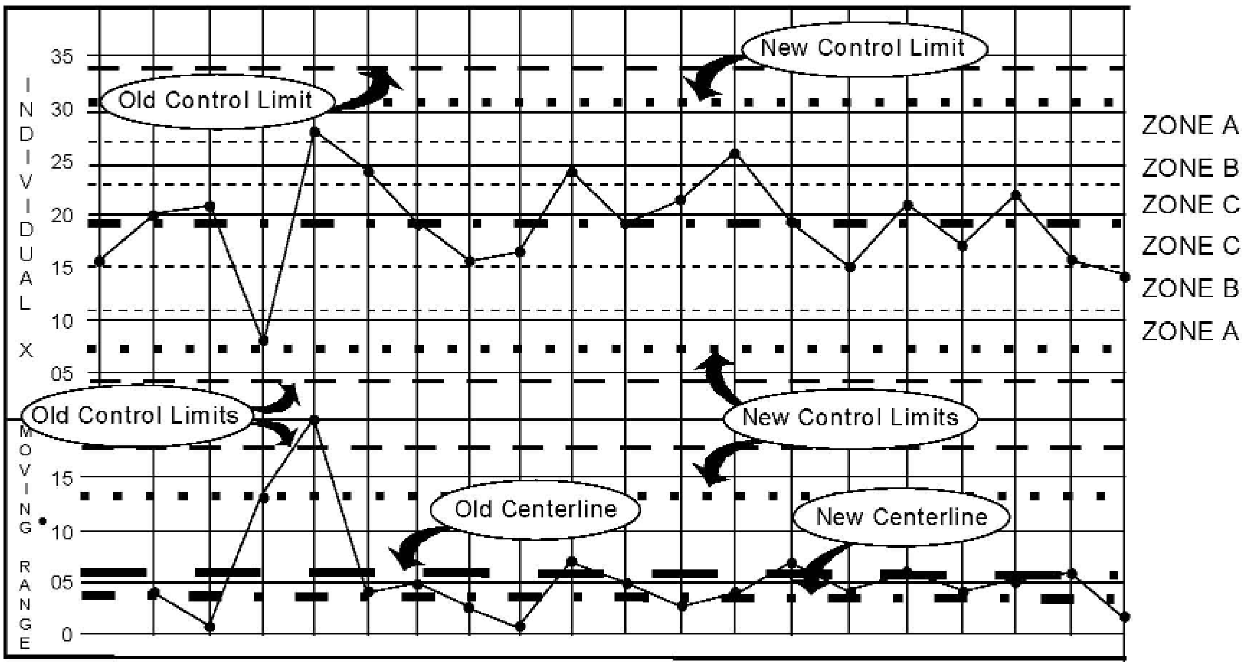
'LCL' is the Lower Control Limit of these values: the calculated limit below the mean line

Typically the UCL and the LCL are within some standard deviation range above and below the Center Line

This next chart is obviously more involved than the first and we provide it here simply as an example of what can be done when you're ready to dig deeper into your measurement program.

EXERCISE 2

XmR Control Chart Revised for Inflated Limits



Note: Solid lines represent the grid used in this module; light dashed lines divide the zones in the upper plot.

This chart presents control data in two ways; the 'Xm' in the upper half (individual median values) and the 'R' in the lower half (moving range), hence the name 'XmR' Control Chart.

Also note the 'Zone' values (A, B, C) on the right-hand side. In standard control chart protocol, 'Zone A' is +/- 3 sigma (standard deviation) from the mean, 'Zone B' is +/- 2 sigma, and 'Zone C' is+/- 1 standard deviation. This is one of the measures used to begin to "tighten the belt" of the process, that is, reduce the range of process variation. These zones must not be confused with the now popular "Six Sigma" mathematical terminology which means '3.4 defects per million opportunities' — DPMO. Now that's a tight process (unless of course you're a frequent flyer and you'd much prefer a 'zero defects' flight safety record!).

For our purpose here, we've kept this as simple as we could since we didn't want to get into a lot of math and charting details, most of which would likely be "TMI" and put many of you into the snooze zone.

For your further edification on control charts and their underlying statistical calculations, however, you might want to start your research with the following:

Module 10 Control Chart:
http://www.balancedscorecard.org/Portals/0/PDF/control.pdf
This is a soup-to-nuts document that is esoteric in spots but is a very complete one-stop control chart primer (and beyond).

American Society for Quality – Quality Tools – Data Collection and Analysis Tools – Control Chart:
http://www.asq.org/learn-about-quality/data-collection-analysis-tools/overview/control-chart.html

Skymark – Classic Tools – Control Charts:
http://www.skymark.com/resources/tools/management_tools.asp
This is a neat little thing that discusses common and special cause variation and out-of-control indicators.

ISixSigma ® – Control Chart Wizard:
http://www.isixsigma.com/control_charts/

At last count, Google produced 57,000,000 'Control Charts' hits; enjoy!

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