The Numbers Game

Successful, innovative companies are those that meet customer needs better than anyone else. Statistical process control techniques can give you hard numbers on how you stack up against the competition.

by Ted M. van Ryn, P.Eng.

Today, when a company consistently delivers high quality goods or services with high productivity rates, low internal costs and competitive pricing, it is almost invariably the result of some form of total quality management (TQM) program. Successfully maximizing quality and productivity, while minimizing the cost of delivering a product or service is by no means a minor management achievement. But it is also no guarantee of continued success, if benchmarks against the competition are not included.

Simply stated, if sustainable success is measured in revenue dollars, and customers vote with their dollars for the supplier that best meets their needs, a successful competitor must be meeting customers' needs better than anyone else. TQM/statistical process control (SPC) provides tools for assessing how well a business is meeting its customers' needs. Applying these same tools to assessing how well a competitor is able to meet these same needs is a natural extension.

Effective quality management begins with measurement data. The measurements selected need to be meaningful in terms of a supplier's capability to meet customer requirements. TQM/SPC can provide the framework and tools to assess capability to meet customer requirements.

Getting competitive with SPC

Two reference texts are particularly useful for learning how to apply SPC to competitive analysis: Originally published in 1956 by the Western Electric Company and now in its eleventh printing, *The Statistical Quality Control Handbook* provides a quick how-to reference on the mechanics of statistical control analysis. Leonard A. Doty's more recent 1996 text, *Statistical Process Control*, describes SPC as an introduction to the broader topic of TQM.

Among Doty's many quality tools and analysis techniques is an effective tool for determining competitor benchmarks—process capability, or Cpk, analysis. Doty's book provides four variations for calculating Cpk based on the nature of the customer's specifications. Whether you measure a given attribute of your own product for process control purposes, or a competitor's product for competitive analysis purposes, the generalized calculation format of the Cpk statistic remains the same.

Putting it into practice

Here's an example to illustrate the Cpk calculation. Let's say we are competing with three other manufacturers to make a widget. Although the widgets available to our customers all look much the same, they tell us they are willing to pay a premium for widgets that meet exacting specifications on a dimensional measurement we will call an inner dimension. We will label ourselves as "us" and our competitors as companies "A", "B" and "C." Let's say we have measurements for this dimension on 30 sample widgets picked at random from our own production and similarly acquired from each of our competitors.

Table 1. Cpk statistics for widget's inner dimensions
(Based on 30 samples)

		Competitors		
	Us	Company A	Company B	Company C
Maximum data value	1.0030	1.0030	1.0030	1.0070
Minimum data value	0.9990	0.9980	0.9980	0.9980
Average	1.0007	1.0004	1.0004	1.0008
Standard deviation	0.001264	0.001331	0.001251	0.001977
Cpk vs 1.00 +/- 0.01	2.45	2.40	2.55	1.56

The sample data shows that we have a slight edge over the competition (see Table 1). Our minimum measurement is 0.999, which is closer to the desired nominal of 1.00, and therefore better than the 0.998 of the competition. And our maximum value of 1.003 is no worse than competitors A and B, and perhaps considerably better than C at 1.007. However, examining the maximum and minimum values does not tell the whole story.

What the customer wants is a supply of widgets with a premium distribution of inner dimension measurements—widgets that consistently exceed the specification. The customer will pay top dollar for a supply of widgets whose inner dimension measures exactly 1.00, without variation. However manufacturing processes vary over time, with changes in operation as production volumes increase, costs decrease, and quality is maintained or improved, or not.

We use the process capability statistic, Cpk, to determine how close we are to achieving the perfection the customer wants. The Cpk is built on the simple descriptive statistics of measurement. The statistic we need to calculate first is the average value, the sum of all the data points in a column divided by the number of data points, which is 30 in this example. The average value measures the central tendency of each column of measurements. In the ideal case for the 1.00 +/- 0.01 specification, we would want to see the average value of our column centered at 1.00, or right on top of the nominal. On each side of this average value, the number of widgets at each measurement value tails off to zero, before we get to the specification limit.

Ideally we want to have zero widgets fall into these tail areas and the distribution of measurements to have a zero spread. Statisticians have developed the standard deviation as the measure of non-zero spread.

The statistical calculations that describe a distribution of measurement values are as follows:

- maximum = the largest value measured;
- minimum = the smallest value measured;
- average = the sum of all the values divided by the number of measurement values, or, = sum (X_1 to X_n) / n;
- standard deviation = square root of the variance;
- variance = the sum of the squares of each difference between the average and measured value, all divided by the number of measurements, or, = ((X_1 - average)^2 + (X_2 - average)^2 + (X_n - average)^2) / n.

The calculation of the process capability statistic, Cpk, in the example then becomes the following: Cpk = the absolute value of the difference between the average and the nearest specification limit (either 0.99 or 1.01, as appropriate), divided by three times the standard deviation.

The measurements in this example form a distribution of values termed two-sided, because the measurements may take on values on either side of the specified nominal, and could be expressed as positive or negative with respect to this nominal. Since other measurement distributions are possible in other cases, quality statisticians have determined a more generalized form of the Cpk definition to apply to all types of distributions, as follows:

- general Cpk = M times the absolute value of the difference between the average and the nearest specification limit, divided by three times the standard deviation, all plus B;
- because M and B remind us of the slope (M = rise over run) and offset (y = B when x = 0) in the equation of the line (y = Mx + B), we can see the general Cpk equation gives Cpk a consistent meaning for all distribution types.

The pitfalls

How you interpret a competitor's process capabilities and the decisions you make in response to a Cpk benchmark may be subject to many considerations unique to your industry and organization. Concerns may arise when you compare the capabilities of you own well-understood, in-house process to competitor A's, B's or C's process–about which you will likely have sparse information. You will need to make many assumptions and judgment calls. The astute analyst will recognize the potential for incorrect assumptions or inappropriate judgment calls, and make every effort to reduce errors with additional competitive intelligence, wherever possible.

One obvious pitfall is the potential for selecting inappropriate sample sizes. It seems intuitive that a sample of several thousand measurements is somehow better than a sample of only 30 measurements. Yet statistical confidence in the result may differ only slightly. You may need the expert assistance of a qualified statistician to eliminate sample size concerns.

Another important consideration is the exact nature of the specifications used in the Cpk analysis. It may be an advantage to define process capability in terms of both the external specifications the customer sees and internal manufacturing specifications. These internal specifications may be buffered from marketplace specifications by internal risk management, or subject to a pre-shipment selection process to meet requirements that cannot be controlled directly in the manufacturing process.

Moving up the value chain

When meeting a customer's requirements on-time-every-time is the focus, it becomes prudent to add a little buffering between the plateaus in the value chain of specifications. The idea is one of "nested" or "chained" specifications: If you make your product to a tighter spec in your plant, then you will always meet the looser spec required by the customer.

The specification value chain may include your own internal, propriety specifications and those of your competitors, generic/published information known by everyone and customer contract specifications known by customers and some competitors, but not by you. What the customer requires may be somewhat less, or more, restrictive than what the industry provides.

Customer specifications may differ significantly from internal manufacturing specifications. Yet without access to all of the proprietary details of competitor processes, we may only be able to directly benchmark what the customer sees. The differences in these hierarchies of specifications appear as differences between what is made, what is shipped and what the customer ordered. Understanding these specification differences helps form more robust, credible and comparable analyses.

Managing the risk (even a small risk) of not exactly meeting customer specifications creates these differences. What the customer sees is the ultimate determinant. However, if internal capability improvements cannot be translated into additional value, competitive advantage has not been created. If you attempt to fool the marketplace by cherry picking your best production, you have not created real competitive advantage. You may simply have bought yourself limited time to improve your process capability and bring internal specifications into line.

Benchmarking competitive capabilities

To illustrate how SPC may be used to benchmark competitive capability over the long term, let us extend the example introduced earlier. As before, we manufacture and market high-tech, expensive widgets made from ultra-pure materials to exacting dimensional specifications. We believe we should charge a premium for each widget, and our corporate culture demands that we place customer satisfaction above other considerations. We see ourselves as quality leaders in whatever we do.

As before, there are only three other competitors manufacturing and marketing similar widgets for this market and its several dozen major customers. We determine from working with our customers that an inner dimension, an outer dimension and an offset between these dimensions are of critical importance to them.

The industry practice is for customers and suppliers to contract a supply of widgets based on a projection of annual requirements for a number of years. Penalties and premiums are agreed upon, based on the delivery volumes expected. As a supplier, we are required to have internal manufacturing process controls in place to ensure that our product meets the specifications. We provide 100 per cent shipment inspection reports of each critical dimension on each widget supplied. As purchaser, our customer has the capability to verify these reports, and monitors each shipment closely.

Over time, as competitors continuously improve widget manufacturing processes to increase quality and productivity, while decreasing cost, the following questions invariably arise: Which set of process control improvements will not only keep us at our target level of quality, but also give us a competitive advantage? Should we focus on exceeding these critical customer specifications, reducing costs, increasing productivity, or on all of these goals combined? Again, a competitive assessment will help answer these questions.

We acquire and measure 30 widgets from competitors A, B and C and compare these to measurements of 30 widgets from our plant production. Using the same measurement procedures as those used in our plant, we calculate the descriptive statistics for each dimension and the Cpks for our measured data (see Table 2).

Based on the desired process capability value ranges shown in Table 2, we conclude that:

- competitor C is disadvantaged for inner dimension process control and will meet, but not exceed, customer specifications. All other competitors may be expected to consistently exceed customer specifications;
- competitor A is disadvantaged for outer dimension control; and
- competitor B is disadvantaged for offset control.

Products from companies A, B and C present different potential issues from the customer's perspective. B's disadvantage may be the most severe. However, communicating these conclusions to customers and competitors is fraught with legal and business issues, which may require additional preparation. Careful consideration of the organization's business practices guidelines, review by legal counsel and review with customer account managers may be necessary, before developing marketing and sales collateral material based on this simple but compelling assessment.

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Table 2. Comparison of widget process capability statistics

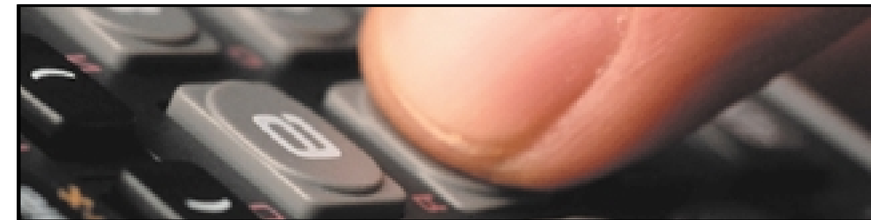
		Competitors		
Cpk, n = 30	Us	Company A	Company B	Company C
Inner dimension	2.45	2.40	2.55	1.56
Outer dimension	2.65	1.35	2.00	2.50
Offset	2.35	2.40	0.91	2.00

Desired process capability value ranges:

Cpk $\geq$ 2 indicates the mean value of the measured distribution is six or more standard deviations away from the nearest specification limit. For normal distributions of measurements, this will reduce the probability of producing an item outside the specification limits to exceedingly low levels, thus almost always exceeding customer requirements.

Cpk $\leq$ 2 and $\geq$ 1 indicates the mean is between three and six standard deviations away from the nearest specification limit, which will likely result in a low but acceptable level of product defect, and meet most customer requirements.

Cpk < 1 shows that the average is less than three standard deviations away from the nearest specification limit. In this case, it's highly likely that the product will only meet the requirements of the least demanding customers.



Reach for the top

The four major steps in applying statistical process control to competitor benchmarks are:

1. Understand your customers' real requirements beyond minimum acceptable specifications. Determine the measurable attribute that customers consider business critical and for which they are willing to pay a premium.
2. Acquire and measure representative samples of both your own and your key competitors product for these attributes. Calculate the descriptive statistics of the attribute measurements and the process capability statistics for your product and your competitors' products.
3. Leverage the comparison of process capability statistics. If you are advantaged, take the information to your marketing people and help create a great sales story. If you are disadvantaged, take the information to your product people and help create a better product.
4. Monitor the marketplace and repeat the steps when anything significant changes, specification changes are introduced, or a competitor introduces an improvement.

References

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