The Keys to Quality Assurance

It takes more than a good capability ratio

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Managers the world over want to know if things are "in control." This usually is taken to mean that the process is producing 100 percent conforming product, and to this end an emphasis is placed upon having a good capability or performance index. But a good index by itself does not tell the whole story. So if you want to learn how to be sure that you are shipping 100 percent conforming product, read on.

CAPABILITY AND PERFORMANCE INDEXES

There are four capability and performance indexes that are in common use today. While many other ratios have been proposed, these four indexes effectively summarize the relationship between a process and the product specifications.

The Capability Ratio uses the difference between the watershed specifications to define the space available and compares this with the generic space required by any process that is operated with minimum variance. This generic space required is computed as six times an appropriate within-subgroup measure of dispersion, *Sigma(X)*.

$$\text{Capability Ratio} = C_p = \frac{UWSL - LWSL}{6\ Sigma(X)} = \frac{\text{space available}}{\text{space required by process}}$$

Thus, the Capability Ratio defines the space available as a multiple of the space required under the best possible circumstances. It describes what the process can do, or approximates what it can be made to do, when it is operated on-target with minimum variance.

The Centered Capability Ratio takes the process location into account by using the distance to the nearer watershed specification, *DNS*, to define the effective space available for the process.

Operating at this distance from the nearer specification is like being centered within specifications having width equal to twice the *DNS* value.

$$\text{Centered Capability Ratio} = C_{pk} = \frac{2\,DNS}{6\,Sigma(X)} = \frac{\text{effective space available}}{\text{space required by process}}$$

Thus, the Centered Capability Ratio defines the effective space available as a multiple of the space required by the process. It describes what will happen when the process is operated predictably at the current process average.

The Performance Ratio uses the difference between the watershed specifications to define the space available and compares this with a characterization of the space used by the process in the past. This space used in the past is computed as six times the global standard deviation statistic, *s*.

$$\text{Performance Ratio} = P_p = \frac{UWSL - LWSL}{6\,s} = \frac{\text{space available}}{\text{space used by process in past}}$$

Thus, the Performance Ratio defines the space available as a multiple of the space used by the process in the past. It describes the elbow room within the specifications if the process is operated in the same manner as in the past. It does not, however, take the process location into account.

The Centered Performance Ratio takes the process location into account by using the distance to the nearer watershed specification, *DNS*, to define the effective space available for the process. Operating at this distance from the nearer specification is like being centered within specifications having width equal to twice the *DNS* value.

$$\text{Centered Performance Ratio} = P_{pk} = \frac{2\,DNS}{6\,s} = \frac{\text{effective space available}}{\text{space used by process in past}}$$

Thus, the Centered Performance Ratio defines the effective space available as a multiple of the space used by the process in the past. This ratio essentially describes the process as it was, where it was, without any consideration of what the process has the potential to do.

HOW THE INDEXES ARE RELATED

The relationship between these four indexes may be seen in Figure 1. While the top tier of Figure 1 is concerned with the process potential, the bottom tier describes the process performance. As a process is operated ever more closely to its full potential, the values in the bottom tier will move up to be closer to those in the top tier.

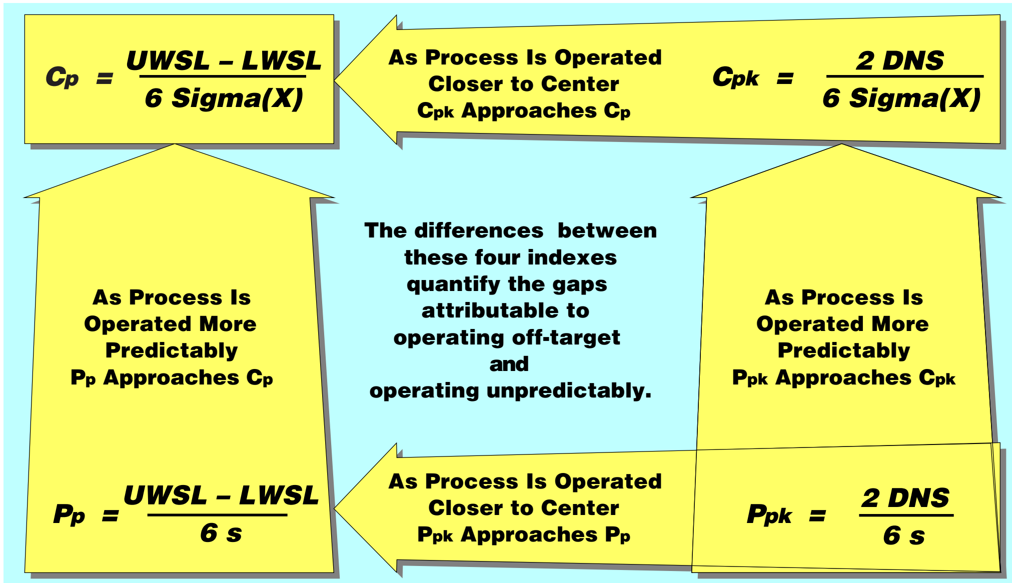

Figure 1: How the Capability and Performance Indexes Define the Gaps Between Performance and Potential

While the left side implicitly assumes the process is centered within the specifications, the right side takes into account the extent to which the process may be off-center. As a process is operated closer to the center of the specifications the values on the right will move over to be closer to those on the left.

When a process is operated predictably and on target, the four indexes will be four estimates of the same thing, and all four index values will be close to each other.

When a process is operated predictably but is not centered within the specifications, the top and bottom tiers will have similar values, but there will be some discrepancy between the values on the right and left sides. This discrepancy will quantify the effects of being off center.

When a process has been operated unpredictably with a historical average that is near the target, the indexes on the right and left sides will be similar, but those in the bottom tier will be smaller than those in the top tier, and these discrepancies top to bottom will quantify the gap due to unpredictable operation.

When a process is operated unpredictably and off target, the four indexes will represent four different quantities.

Thus, while the Capability Ratio, C_p, will always be the best-case value, the Centered Performance Ratio, P_{pk}, will describe the past process performance. The gap between these two values is the opportunity that exists for improving the current process by learning how to operate it up to its full potential.

FOUR PROCESSES

Process One has the following Capability and Performance Indexes. What can we say about this process based on these four index values?

$C_p = 1.48$ $C_{pk} = 0.95$

$P_p = 1.43$ $P_{pk} = 0.92$

Process One is being operated predictably but off-center. In spite of being off-center the specifications are wide enough for the process to still be essentially capable of meeting specifications. At this point the supervisor scheduled a retooling to move the average back to the midpoint of the specifications.

Process Two has the following Capability and Performance Indexes based on one week's worth of production. What can we say about this process based on these four index values?

$C_p = 5.38$ $C_{pk} = 2.00$

$P_p = 2.40$ $P_{pk} = 0.90$

While three of these four values are nice and large, the discrepancies between the capability ratios and the performance ratios tell us that this process is being operated unpredictably. The discrepancies left to right suggest this process is not being operated near the mid-point of the specifications. The large values tell us the specifications are rather wide. The huge difference between P_{pk} and C_p suggests that a large opportunity exists for process improvement. However the unpredictable operation undermines any predictions regarding the future performance of this process. To illustrate this inherent unpredictability the four indexes for the next week of Process Two were:

$C_p = 5.60$ $C_{pk} = 4.05$

$P_p = 0.82$ $P_{pk} = 0.59$

The only index that did not change by a substantial amount is the capability ratio, which, in this case is merely hypothetical. Until this process is operated predictably we simply cannot use the data from the past to characterize what will actually happen in the future. (What part of the word un-pre-dict-able is not clear?)

Process Three has the following Capability and Performance Indexes. What can we say about this process based on these four index values?

$C_p = 0.42$ $C_{pk} = 0.33$

$P_p = 0.29$ $P_{pk} = 0.22$

Process Three is being operated unpredictably and off-center. In the past it produced 38 percent nonconforming product (which is consistent with the performance index of 0.29). Moreover, with a capability ratio of 0.42, this process does not appear to be capable of meeting the specifications even if operated predictably and on-target.

In this case they found assignable causes and made them part of the set of controlled inputs for this process. After doing this they had a predictable process which I have labeled Process Four.

Process Four had the following Capability and Performance Indexes.

$C_p = 0.75$ $C_{pk} = 0.71$

$P_p = 0.72$ $P_{pk} = 0.69$

The convergence of these four indexes confirms that they are now operating this process predictably and on-target. When a process is operated predictably and on-target with a capability near 0.75 it may be expected to produce up to about 2 percent nonconforming product.

It is worthwhile to note that, when it was operated predictably, the actual, achieved capability of 0.75 was much better than the hypothetical capability ratio of 0.42 found originally. This is typical of what happens. As we move assignable causes from the set of uncontrolled factors to the set of controlled process inputs we remove substantial amounts of variation from the process. In this way we usually find that our final capability ratio is much larger than the original, hypothetical capability ratio. This means that the gap between C_p and P_{pk} will usually underestimate the improvement to be found by learning how to operate a process predictably.

So, while computations cannot replace graphs, they can complement them. The four capability and performance indexes, when taken together, begin to tell the story that is completed by the graphs.

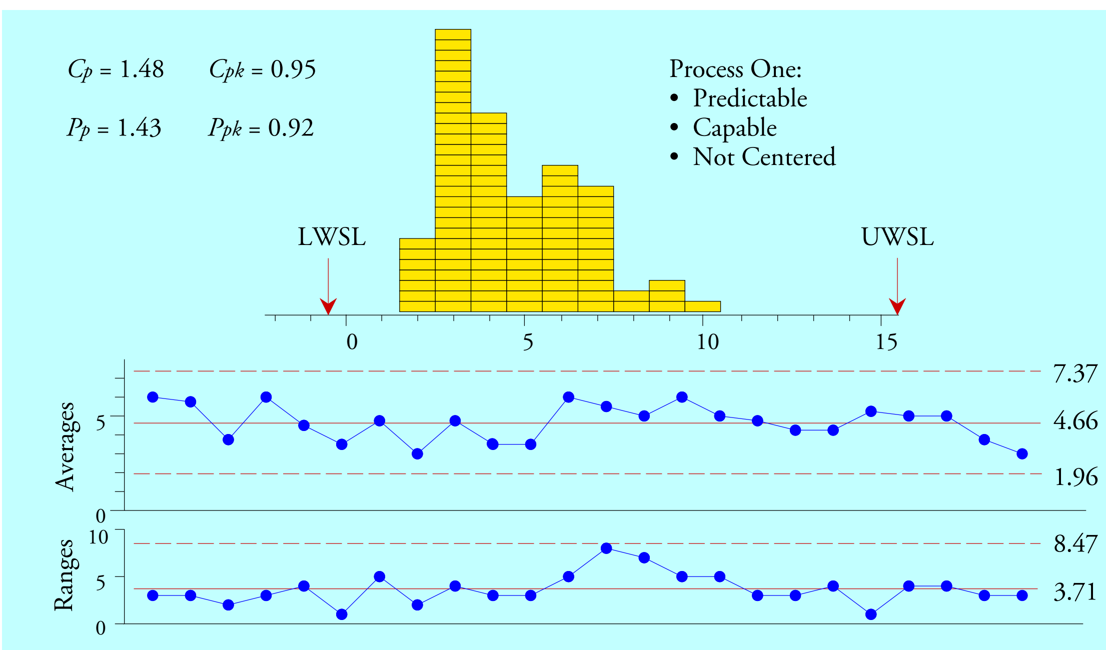

Figure 2: Process One

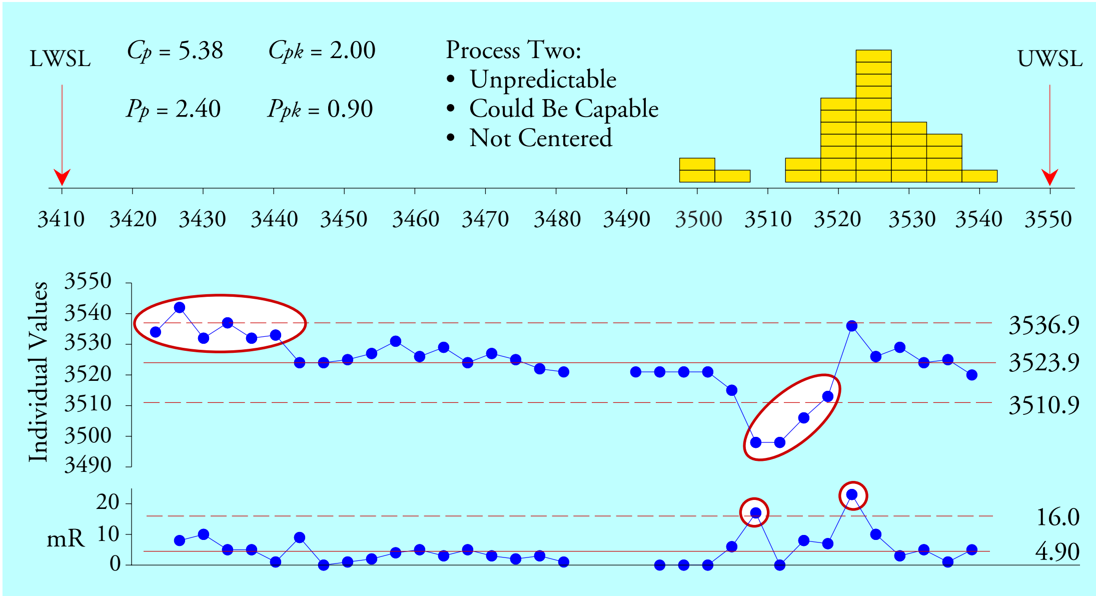

Figure 3: Process Two

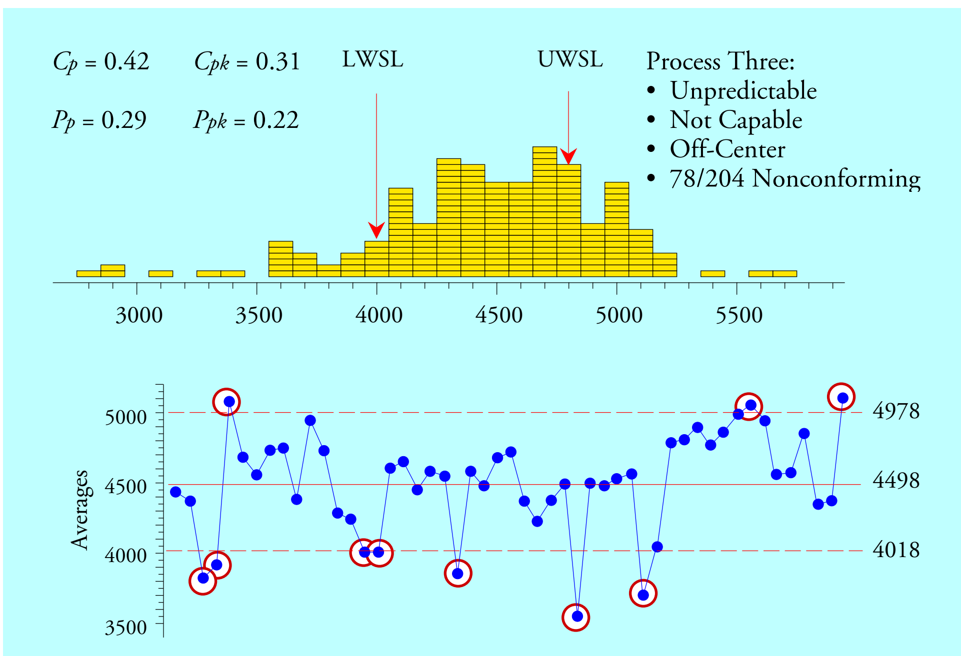

Figure 4: Process Three

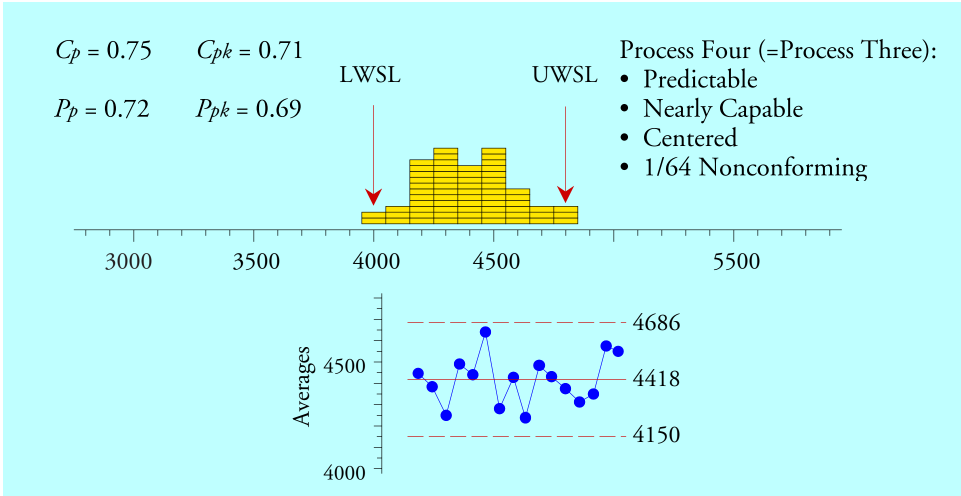

Figure 5: Process Four

THE KEYS TO SHIPPING GOOD PRODUCT

Whenever nonconforming product is made some of it will always get shipped. So the only way to be sure that you are shipping conforming product is to avoid making any nonconforming product. To do this you will need to have three things happen: you will need to have a process with more than a minimum capability; you will need to operate that process predictably; and you will need to have some way to detect when the process strays from operating on-target.

You will need to have a capability greater than 1.00 simply because even the most predictable processes will have occasional upsets. Having a capability in the neighborhood of 1.50 or greater will give you some cushion. This cushion will allow you to detect these upsets without the risk of large amounts of nonconforming product being produced. So while a good capability is *necessary* to guarantee conforming product, the possibility of process changes makes having a good capability not *sufficient* by itself.

You will also need to operate your process predictably simply because the essence of process capability consists of a description what will be produced in the future. Since our data are always historical, we will need to have some basis to extrapolate from the data of the past to a description of what is likely to be produced in the future. When a process is operated predictably the past will provide a rational basis for predicting the future. Thus, predictable operation is *necessary* to guarantee conforming product, but operating a process predictably is not *sufficient* to guarantee conforming product by itself.

You will also need to operate your process on-target. When the process capability is less than 1.10 the only way to minimize nonconforming product will be to operate on-target. When the process capability is larger than 1.10 we will still need to operate on-target to maximize the cushion afforded by the wider specifications. On-target operation is important simply because entropy will always result in occasional process changes. The discipline of operating a process predictably and on-target will result in the timely detection of these changes and will allow for appropriate interventions. So, while operating on-target is *necessary* to minimize the opportunities for non-conforming product, on-target operation is not *sufficient* to guarantee conforming product.

All three of these necessary conditions must be present in order to guarantee conforming product. These necessary conditions only become sufficient when they all occur together. When a process is operated predictably and on-target the four capability and performance indexes will converge to the same value. When this common value is 1.50 or greater we can be reasonably assured that, barring some unforeseen upset, the process will be producing nothing but conforming product. And the best way to be aware of any upsets will be to use a process behavior chart in real time.

Thus, by comparing the four capability and performance indexes you can quickly and easily get some idea about how a process is being operated and whether or not it is likely to possess a sufficient capability to guarantee conforming product. But the only way to guarantee conforming product requires the active use of process behavior charts to achieve and maintain a predictable and on-target process.