The Gaps Between Performance and Potential

Using the Effective Costs of Production and Use

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In my column of August 2 I defined the *Effective Cost of Production and Use* and showed how it can be obtained directly from the Capability and Performance Indexes. In this column I will show how these indexes can be used to estimate the benefits to be obtained from different improvement strategies.

THE CAPABILITY AND PERFORMANCE INDEXES

The Capability Ratio, C_p, compares the space available within the specifications with the space required by the process. The Performance Ratio, P_p, compares the space available within the specifications with the space used by the process in the past. The only difference between these two ratios is the manner in which the denominator is computed. The Capability Ratio uses a within-subgroup measure of dispersion, *Sigma(X)*, while the Performance Ratio uses a global standard deviation statistic, *s*. When a process is operated predictably these two measures of dispersion tend to converge and the two ratios will be quite similar. However, when a process is operated unpredictably the global measure of dispersion will be inflated relative to the within-subgroup dispersion, which will deflate the Performance Ratio.

In a similar manner, the Centered Capability Ratio, C_{pk}, compares twice the Distance to the Nearest Specification, 2 *DNS*, with the space required by the process, while the Centered Performance Ratio, P_{pk}, compares 2 *DNS* with the space used in the past. Thus, these four index numbers are related in the manner shown in Figure 1.

The top tier in Figure 1 represents the actual capability of a predictable process, or the hypothetical capability of an unpredictable process. The bottom tier represents the actual past performance of a process.

The left side of Figure 1 describes the potential or the performance of a process that is centered at the mid-point of the specifications, while the right side describes how the potential or performance suffers when the process is not centered within the specifications.

When a process is operated predictably and on target these four indexes will be four estimates of the same thing. For example, the Tokai Rika data given in my August column came from a process that was being operated predictably and on target. Those data have index numbers of C_p = 2.26, C_{pk} = 2.21, P_p = 2.40, and P_{pk} = 2.35.

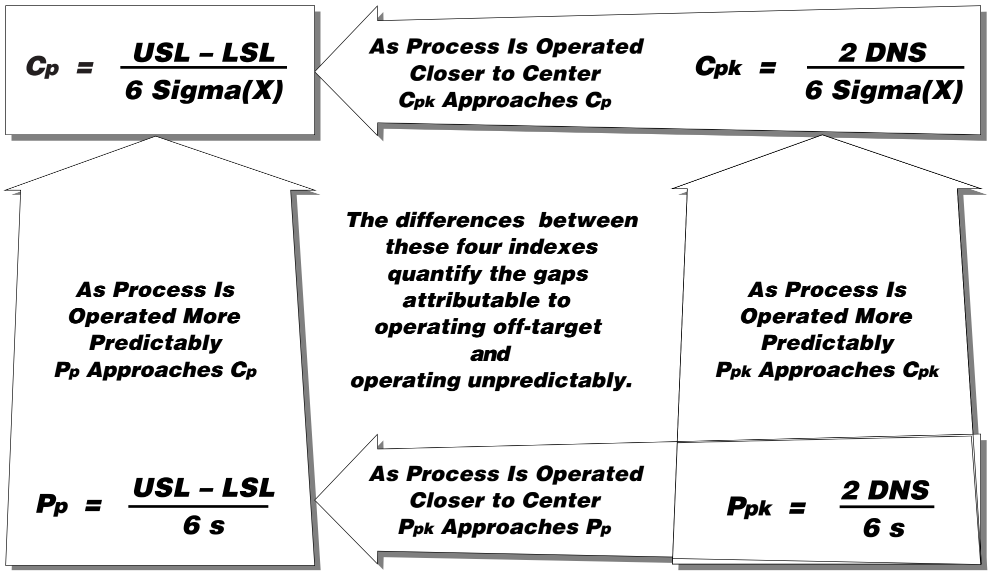

Figure 1: The Capability and Performance Indexes

When a process is operated predictably but is not centered within the specifications there will be a discrepancy between values on the right and left sides in Figure 1.

When a process is being operated unpredictably the indexes in the bottom tier of Figure 1 will be substantially smaller than the indexes in the top tier.

Finally, when a process is operated unpredictably and off target the four indexes will be estimates of four different quantities. While the Capability Ratio will be the best-case value, the Centered Performance Ratio will be the worst-case value, and the gap between these two values will define the opportunities for improvement connected with operating the process up to its full potential.

THE BATCH WEIGHT DATA

The data in Table 1 are the weights of 259 sequential batches. The specifications are 900 kg to 1100 kg, with a target value of 1000 kg. The process behavior chart is shown in Figure 2.

The average of the first 59 moving ranges is 25.8, which results in a *Sigma(X)* value of 22.9. Thus, the Capability Ratio is found to be 1.46.

The average of the first 60 values is 938.1. This results in a *DNS* value of 38.1, and a Centered Capability Ratio of 0.55. The discrepancy between 1.46 and 0.55 summarizes the extent to which this process is off target.

The global standard deviation statistic for the 259 Batch Weights is s = 61.3. Thus, the Performance Ratio is 0.54. The average of all 259 values is 937. This results in a *DNS* value of 37 and a Centered Performance Ratio of 0.20.

Table 1: Batch Weight Data

Batch No.	*Batch Weights (kilograms of product exiting blender)*									
1-10	905	930	865	895	905	885	890	930	915	910
11-20	920	915	925	860	905	925	925	905	915	930
21-30	890	940	860	875	985	970	940	975	1000	1035
31-40	1020	985	960	945	965	940	900	920	980	950
41-50	955	970	970	1035	1040	1000	1000	990	1000	950
51-60	940	965	920	920	925	900	905	900	925	885
61-70	1005	1005	950	920	875	865	880	960	925	925
71-80	875	900	905	990	970	910	980	900	970	900
81-90	895	885	925	870	875	910	915	900	950	880
91-100	910	965	910	880	900	920	940	985	965	925
101-110	925	975	905	890	950	975	935	940	900	915
111-120	980	880	905	915	960	900	915	920	865	980
121-130	935	840	900	965	890	875	1020	780	900	900
131-140	800	960	845	820	910	885	940	930	925	850
141-150	965	1010	1030	980	1010	950	940	1005	880	930
151-160	845	935	905	965	975	985	975	950	905	965
161-170	905	950	905	995	900	840	1050	935	940	920
171-180	985	970	915	935	950	1030	875	880	955	910
181-190	1050	890	1005	915	1070	970	1040	770	940	950
191-200	1040	1035	1110	845	900	905	910	860	1045	820
201-210	900	860	875	1005	880	750	900	835	930	860
211-220	960	950	1020	975	950	960	950	880	1000	1005
221-230	990	1020	980	1020	920	960	1000	1000	860	1130
231-240	830	965	930	950	945	900	990	865	945	970
241-250	915	975	940	870	890	915	935	1060	1015	1100
251-259	810	1010	1140	805	1020	1110	975	970	1090	

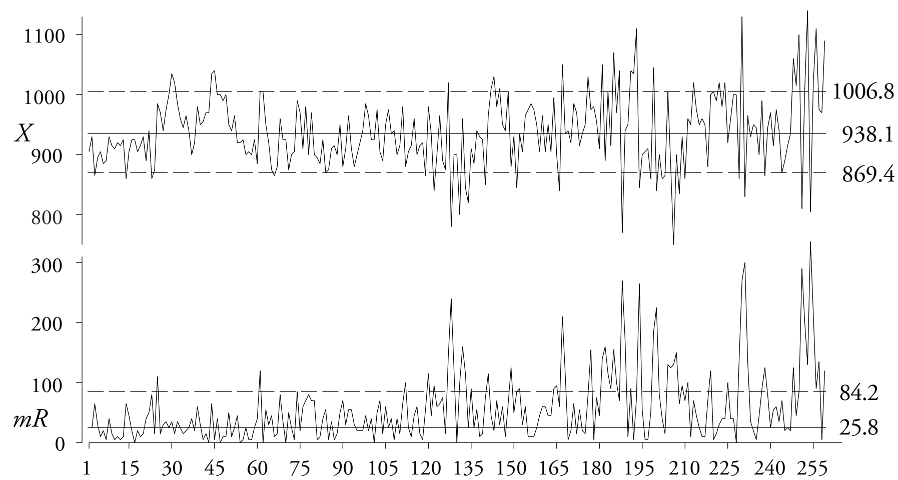

Figure 2: *XmR* Chart for the Batch Weight Data

The discrepancy between C_p =1.46 and P_p = 0.54 quantifies the extent to which this process is being operated unpredictably.

THE BASELINE COSTS OF PRODUCTION AND USE

We use P_p and P_{pk} to find a baseline value for the *Effective Cost of Production and Use*. While it may be difficult to predict what an unpredictable process is going to do in the future, we can be reasonably sure that spontaneous improvement is highly unlikely. If we do not do anything, the future is unlikely to be any better than the past, and it could be worse. Therefore, by characterizing the *Baseline Costs of Production and Use* for the past we have a reasonable value for purposes of comparison. In this case all nonconforming product is scrapped, and the cost of scrap is close to the nominal cost of production. Using the tables provided in my new book ***Reducing Production Costs*** we find an *Excess Cost of Production* of 0.394, an *Excess Cost of Use* of 0.301, and an *Effective Cost of Production and Use* of 1.694. At a nominal cost of \$500 per batch, and with an annual volume of 13,000 batches, this works out to a baseline annualized excess cost of:

$$\textit{Baseline Annualized Excess Cost} = 0.694 \times \$500 \times 13{,}000 = \$4{,}511{,}000$$

If they could wave a wand and make things perfect, this is the potential amount they could save over the course of a year. Since perfection is unlikely to occur, this 4.5 million dollars represents the opportunity pool that exists for improvement projects. (Such opportunity pools are sometimes known as entitlements.) In this case, because the producer and the customer are separate departments in the same company, it is appropriate to use both the *Excess Costs of Production* and the *Excess Costs of Use* in defining this opportunity pool.

THE CENTERED COSTS OF PRODUCTION AND USE

Recall what happens when a process is operated on target. As the process average gets closer to the mid-point of the specifications, the value of the Centered Performance Ratio, P_{pk}, will approach the value of the Performance Ratio, P_p. Thus, if we compute the *Effective Cost of Production and Use* for the case where $P_{pk} = P_p$ we will approximate the cost that will exist when the process is operated on target. We will call these values the Centered Costs.

The difference between the Baseline Costs and the Centered Costs will be the potential savings that are likely to be realized by improving the process aim. Since efforts to improve the process aim are some of the easier types of process improvements, it is helpful to see what can be gained by this approach.

For the Batch Weight Data the Performance Ratio is $P_p = 0.54$. With $P_{pk} = P_p = 0.50$ we find the *Excess Cost of Production* to be 0.154, the *Excess Cost of Use* is 0.245, and the *Effective Cost of Production and Use* is 1.399. This represents a centered annualized excess cost of:

$$\textit{Centered Annualized Excess Cost} = 0.399 \times \$500 \times 13{,}000 = \$2{,}593{,}500$$

This is \$1.9 million lower than the Baseline Cost. Thus, we would estimate that we can save almost two million dollars per year by simply operating this process closer to the target value of 1000 kg. Of these savings, approximately 1.5 million will be in reduced costs of production (less scrap), and the remainder will be in reduced costs of use (the product works better at the next step in the process).

THE PREDICTABLE COSTS OF PRODUCTION AND USE

For the Batch Weight Data the Capability Indexes are C_p = 1.46 and C_{pk} = 0.55. Rounding these off to 1.50 and 0.60 we find an *Excess Cost of Production* of 0.037, an *Excess Cost of Use* of 0.380, and an *Effective Cost of Production and Use* of 1.418. This would translate into a predictable annualized excess cost of:

$$\textit{Predictable Annualized Excess Cost} \;=\; 0.418 \times \$500 \times 13{,}000 \;=\; \$2{,}717{,}000$$

Compared with the Baseline Cost this represents a savings of $ 1.794 million. The *Excess Cost of Production* is estimated to have gone from 0.394 to 0.037, which translates into over $ 2.3 million in savings, but the increased consistency about the historical average, which is off target, will result in an increase in the *Excess Cost of Use* from 0.301 to 0.380, which translates into a loss of over $ 500,000.

Fortunately, as we identify Assignable Causes and make them part of the set of Control Factors, we will usually gain additional leverage for adjusting the process aim. This means that we can usually operate closer to target as we learn how to operate a process predictably. Since these Predictable Costs postulate predictable operation at the historic average, they will generally understate the potential payback from operating predictably. For this reason, we may occasionally skip the Predictable Costs and go on to find the Minimum Costs.

THE MINIMUM COSTS OF PRODUCTION AND USE

Operating predictably and on target is equivalent to operating on target with minimum variance. When we do this we are operating our process up to its full potential. And this potential is characterized by the Capability Ratio, C_p. By finding the *Effective Cost of Production and Use* that corresponds to $C_{pk} = C_p$ we can describe what our process has the potential to do. By comparing these Minimum Costs with the Baseline Costs we can approximate the savings to be achieved by operating our process predictably and on target.

The Batch Weight Data has a Capability Ratio of C_p = 1.46. With C_p = 1.50 and C_{pk} = 1.50 we find an *Excess Cost of Production* of 0.000, an *Excess Cost of Use* of 0.049, and an *Effective Cost of Production and Use* of 1.049. This would translate into a minimum annualized excess cost of:

$$\textit{Minimum Annualized Excess Cost} \;=\; 0.049 \times \$500 \times 13{,}000 \;=\; \$318{,}500$$

all of which would be *Excess Cost of Use*. Compared with the Baseline Cost of $ 4.5 million, this is a potential savings of $ 4.2 million per year just from learning how to operate this process up to its full potential. Finally, with excess costs that amount to less than 5% of the nominal costs (*ECP&U* = 1.049), there is not much need to think about process upgrades or reengineering here. The current process has the potential to meet the requirements for some time to come.

Table 2: The Excess Costs for the Batch Weight Data

	ExCP	*ExCU*	Total	
Baseline	$ 2,554,500	$ 1,956,500	$ 4,511,000	What Was
Centered	$ 1,001,000	$ 1,592,500	$ 2,593,500	If Operated On Target
Predictable	$ 247,000	$ 2,470,000	$ 2,717,000	If Operated Predictably @ Old Average
Minimum	—	$ 318,500	$ 318,000	If Operated Predictably & On Target

These various excess costs of production and use may be displayed in tabular form for emphasis. For the Batch Weight Data example, where we had annualized costs, this table might look like Table 2. Of course, once we have Table 2, it is logical to follow with Table 3 which shows the potential savings for different courses of action.

Table 3: Estimated Annual Savings for Various Process Improvements for Batch Weights

	Savings at Production	*Savings in Use*	*Total Savings*
If Operated On Target	$ 1,553,500	$ 364,000	$ 1,917,500
If Operated Predictably @ Old Average	$ 2,307,500	$ – 513,500	$ 1,794,000
If Operated Predictably & On Target	$ 2,554,500	$ 1,638,000	$ 4,193,000

By converting Capability Indexes and Performance Indexes into tables like these you will find it much easier to get the support for needed process improvements. It will also help you to avoid working on projects with little potential for payback. For more information about how to convert Capability and Performance Indexes into *Effective Costs of Production and Use* see ***Reducing Production Costs*** which is now available from SPC Press.

In next month's column we will look at what the *Effective Cost of Production and Use* tells us about economic operation.