Process Capability in Administrative Applications

by
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In measuring administrative functions it is necessary to establish not only the process average—the current performance of the output of a group of clerks, sales personnel, or the like—but also to determine at what level of quality they can perform given the system in which they operate. This level of quality is called the process capability.

The definition of process capability in administrative functions differs in two ways from the usual definition in the literature. First, the former deals with attribute rather than variables measurement. Second, the usual definition of process capability is inadequate even for manufactured product and at times is utterly misleading.

The normal concept of process capability is given as the limits expected for individual items based on control chart measurements and the assumption that the individual items are distributed normally. This assumption of normality is often unjustified. Furthermore, if the measurement is on a mixture—such as the output of two or more machines, mold cavities, operators, or the like—it is easily possible that a particularly poor part in the mixture inflates the measures. What is desired is the capability of those components of the mixture that represent the common cause system.

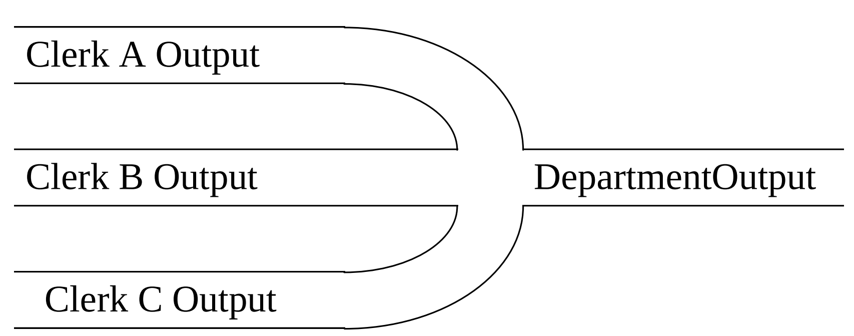
Clerical and administrative measurements are almost always a mixture. Thus the method (described below) of determining the process capability of mixtures and identifying potential outliers has great application in administrative and clerical functions, and also has relevance in all process capability studies.

The most common approach to clerical quality control is to measure the total quality of the department output—the process average—to define the process capability. This, however, can be an extremely misleading measurement. For the true quality attainable by a clerical department is often far better than what is represented by the basic process average.

Figure 1 shows why this is so. The department output is the weighted output of each individual clerk. But suppose Clerk A operates at a quality level that is much worse than that of Clerk B or Clerk C. This subnormal work when mixed with the good work in the process stream, drives the process average far below the capability of Clerk B and C. If Clerk A's quality efficiency were brought to the level of the other two clerks, then the department's process average would improve to its "real" process capability, representing a more valid quality control measurement in the clerical operation.

In order to do this, though, Clerk A must be identified—something that does not happen under a normal analysis of the process average. Let us now examine an iterative process for determining borderline, subnormal contributions to the process aver-

Figure 1 The Workflow Pipeline



age of the clerical operation and thus, for determining process capability.

Clerical or administrative quality control is a system of control exercised in a paperwork environment. Such an environment is quite distinctive from manufacturing. The "product" is usually a complicated transaction: an edited form, typed work, a data entry, a telephone call, etc. Since the nature of a service product is less tangible than that of a manufactured product, it is less easy to define. Furthermore, the producer is not a machine, but a human being, subject to moods and attitudes causing errors to appear in random patterns.

Finally, since the output of clerical operations is almost never subject to continuous measurement, the less efficient measure of "attributes" (right/wrong) is usually employed in designing a clerical quality control system. Such systems measure the percent of nonconformance observed in the sample work, usually a predetermined number of completed items or the number of items completed in a given period of time. Observed errors are related to the sample size and expressed as the percent.

Most schemes of clerical quality control use some form of dependent verification either by a supervisor1, 1 a fellow clerk[2], an independent inspector[3], or other means[4].

The whole function of managing quality in clerical or administrative operations is based on the process capability. Because of its vital importance in the decision process, it is necessary to obtain as good an estimate as possible.

Process capability is estimated by observing the system: in the clerical application it is estimated from the departmental error rate. The raw error rate is the process average, which may or may not be a good estimator of the process capability. As indicated before, the raw error rate process average comes from data from all clerks in the study. Since it is possible for one or more of these clerks to be operating at a quality level that is worse (even in borderline terms) than the others, the process average may be biased to the extent that the true process capability is not reflected.

The following are arithmetic and related graphical techniques that attempt to estimate the process capability by identifying borderline producers in the process average.

To follow the algorithm for determining the process capability, consider the data shown in Table I from a small department of four clerks. The steps for the algorithm are as follows,

1. Record the errors found among the items sampled for each clerk as shown in Table 1.
2. Obtain the process average by dividing the sum of the errors by the sum of the items sampled. In the case of the example the process average is P_a = 40/2304 = 0.017 or 1.7%.

Table 1. Example of Determining Process Capability

Operator	Errors found (r)	Items Sampled (n)	Error rate (Pi)	Initial Value of ti	Final Value of ti
A	3	540	0.60%	-2.10	-1.33
B	9	594	1.50%	-0.41	0.77
C	10	740	1.40%	-0.80	0.45
D	18	430	4.20%	3.89	5.80
Total	40	2,304	1.70%	-----	----

3. Set the process capability, p', equal to the process average ($p'=P_a$ = .017).
4. Test the error rate, Pi, of each clerk against the process capability using the t-test.

$$t_{A,1} = \frac{P_i - p'}{\sqrt{(p' \times (1-p')/n)}}$$

$$= \frac{0.006 - 0.017}{\sqrt{(0.017 \times (1-0.017)/540)}}$$

$$= -2.10$$

This example is for clerk A and the initial value of t. The others are computed in a similar fashion and the results are recorded in the column labeled "Initial value of t_i."

5. Review the work of any clerk whose value of t is three or more. Clerk D in Table 1 is in this category. If a special cause is found, remove the errors and item count of such a clerk from the sums used in step 2.

6. Recompute the process average using the sum of errors and sum of items sampled of the remaining clerks. In this case, the recomputed value is P_a = 22/1874 = .012 or 1.2%.

7. Repeat steps 3 through 6 until the value of P_a no longer changes. The result is the estimate of the process capability.

The last column of Table 1, "Final value of t_i," shows the results of step 4 using the final process average of 1.2% as the system process capability.

After the process capability has been determined, it is necessary to review the data of any operator whose value of t is -3 or less. If a special cause is determined for any such operator, that operator's errors and sample volume is removed from the total and the algorithm repeated for steps 2 through 7.

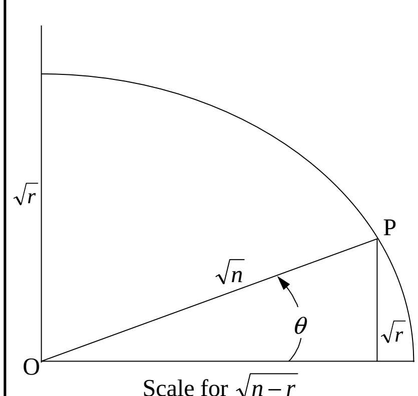
The purpose of removing the outliers on the plus side first is based on the view that if there are operators who are 3 sigma or more removed from p' they inflate the value of p'. The actual process capability, therefore, is less than p'. Operators who are -3 sigma or less from this initial value of p' may well be within control limits when the true value of the process capability has been determined.

Removing operators who fall below the lower control limit is not justified until all outliers above the upper control limit are removed.

The control limits were set at ±3 sigma in the algorithm. Dr. Walter Shewhart[5] found that these limits give the best economic balance between two mistakes. The first mistake is saying something is a special cause when it is not. The second mistake is saying something is not a special cause when, in fact, it is one. The limits were established by experimentation and do not reflect any probability statement. Over the years the ±3 sigma limits have proven efficacious.

In spite of the relative simplicity of the algorithm, it does require some computation. There is a graphic method which avoids the computations altogether[6]. This method uses a special graph paper invented by Mosteller and Tukey[7]. They called it "Binomial Probability Paper or BIPP[8]. This graph paper is laid out as the square root of the number shown on both the abscissa and the ordinate.

Figure 2. Arcsin Transform



The use of the square root scales takes advantage of the geometric relations of è = arcsin (r/n), as Figure 2 shows. If we plot the square root of the errors on the ordinate and the square root of the sample volume less errors (the square root of the number of good items in the sample) on the abscissa, the resultant angle of line from the origin through the point, OP (called a split), is known as the arcsine transform of p = (r/n). Sir Ronald Fisher discovered that this value is nearly normally distributed with individual variance of nearly 1/(4n) (when the angles are measured in radians.)[9] The standard deviation is given as 1/(2 n). On the Binomial Probability Paper a single standard deviation is the 1/2 the distance from 0 to 1 on the abscissa. On most BIPP charts the distance from 0 (the origin) to 1 is 0.4 inch. One standard deviation is then a distance of 0.2 inches (or 5 millimeters.)

To compute the process capability, using the graph paper, first plot the points for each operator. Then draw the split from the origin to the point of total errors (r) on the ordinate and total number of good items (n-r) abscissa. Lay off 3 sigma (0.6 inches) perpendicular to the split.

If all the points lie within the control limit, the process capability p'= r/n. If any of the points fall above the upper control limit, determine if a special cause exists. If so, remove the errors and sample volume and plot a new split with the revised data. Continue until all points with special causes have been removed. (See Figure 3a and 3b on the next page.)

In plotting points on the BIPP it is necessary to correct for continuity. This is done by plotting the triangle resulting from adding 1 to r and adding 1 to n-r as shown in Figure 4a.

Figure 4b illustrates the correction for continuity when r = 1 and n = 2. The resultant value is the center of the hypotenuse. It can be seen that this will need to be done only if the values of r and n are very, very small. As r and n increase, the triangle rapidly converges to a point.

BIPP charts usually come scaled with a maximum value of 600 on the abscissa and 300 on the ordinate. When the data exceeds these values, the scales are contracted by multiplying them with the appropriate factor. If the factor ten is applied to both scales, the tenth scale usually drawn on the top of the BIPP chart is used to set the limits. This scale has a distance of 0.063 inches per standard deviation (0.2 inches divided by 10.)

If only one scale is contracted by a ratio of multiples of ten to the other scale, the full scale units are used to set the 3 sigma limit lines. However, they are plotted perpendicular to the contracted scale instead of perpendicular to the split[10].

As a matter of convenience, the author uses a transparent ruler with a center line and two pairs of parallel lines at distances of +0.1897 inches and +0.6 inches from the center These lines represent, respectively, the ±3 sigma limits for the “tenth scale” and “full scale.” The ruler was easily constructed by drawing the original lines on paper, then making an overhead transparency and trimming to size.

In using the ruler, the data points are plotted as described above but lines are not drawn on the paper. Instead, the center line of the ruler is placed on the origin and the coordinate point for the total. Since the ruler is transparent, points with special cause points—points that lie outside of the three sigma limits—are easily identified. Revised totals are obtained and the center line of the ruler shifted to the new point.

Figure 4a. BIPP Triangle Plot Method

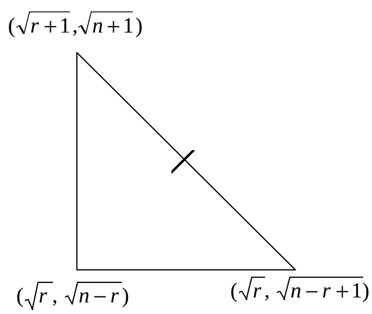


Figure 4b. Detail of BIPP Chart

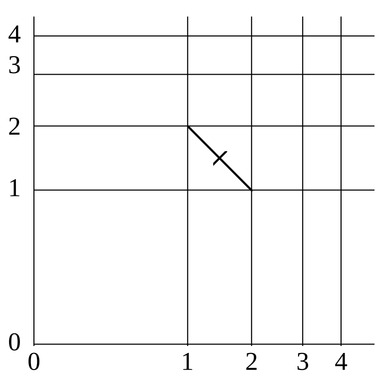
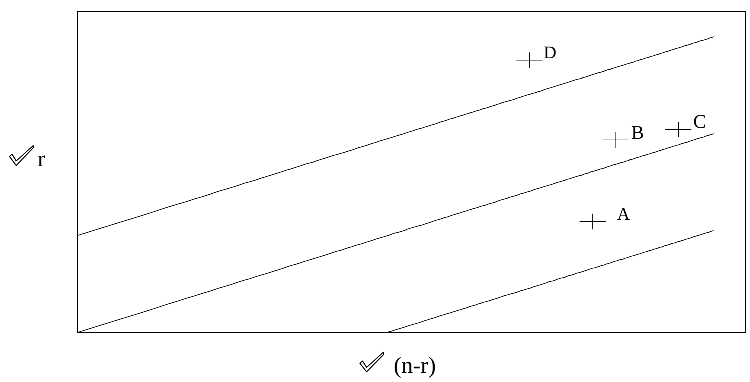


Figure 3a. Initial Plot of Data from Table 1 (Pa = p' = 1.7%)

Figure 3b. Final Plot of Data from Table 1 (Pa = p' = 1.2%)



When no additional points indicate special causes, the estimate of the process capability can be read from the intersection of the ruler's central line and the line marked "100" on the abscissa.

For large masses of data where sophisticated calculators or computers are available, the mathematical approach to process capability is simple enough to use. Otherwise, the graphic approach is really quite simple and well suited for use by clerical personnel.

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Note: This paper is a revision based on the author's original article: Latzko, William J., "Process Capability in Administrative Applications", *Quality Progress* Vol. 18, No. 6 (June 1985) pages 70-73.