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A TOOL TO MONITOR PROCESSES

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Abstract

The purpose of this paper is to present a method which will enable the manager to make comparisons of the quality performance of a set of product lines so that the management's attention is concentrated where it is most needed. The comparison is usually difficult because the different lines may produce different parts with different properties or with the same properties but different specifications. The method proposed in this paper uses three Z values, which are described below (For other management tools, see, for example, Holmes (1986), and Holmes and Mergen (1989). An example of the use of the proposed measures is also discussed.

1. Introduction

Suppose a plant has two product lines; say product A and product B. Assume that three quality characteristics for product A and two for product B are being checked. SPC (Statistical Process Control) personnel may have separate charts to monitor each characteristic of each product line. Management, however, needs to know how the plant is doing overall. The charts used by the SPC people at the operational level are too detailed for management and comparisons of different characteristics and/or the product lines, which have different units of measures, are difficult. This paper presents three measures, which will allow management to evaluate quality performance in three areas:

1. Conformance to Nominal (process target value)
2. Conformance to tolerance (process width)
3. Ability to maintain statistical control (process stability).

By using the three values proposed in this paper, management could answer such questions as: "Is the process centered on nominal with respect to quality characteristics 1, 2, and 3?", "Is the process capable of satisfying the specification limits set for the characteristics 1, 2, and 3?", "Is the process in statistical control with respect to characteristics 1, 2, and 3?"

2. Proposed model

The three Z values proposed in this paper provide the following information about:

1. *How close the average is to the nominal of the specifications, Z-Nominal (Z_N)*
2. *How the width of the process compares with the desired width, Z-Sigma (Z_S) – where actual width is defined as six standard deviations and desired width is defined as upper specification limit (USL) minus lower specification limit (LSL).*
3. *The state of statistical control (i.e., stability) of the process, Z-Control (Z_C).*

1. Z-Nominal (Z_N):

Z_N is used to show the condition of the process center relative to the process nominal. Z_N is defined as follows:

$$Z_N = \frac{(\text{Average - Nominal})}{\frac{s}{\sqrt{n}}} \qquad (1)$$

where average is the process average in a given time period, s is the process standard deviation in a given time period, and n is the number of observations in a given time period.

This measure is similar to the T-rate system developed and used by the Bell Laboratories (see Hodley (1981)). Note that we are using Z rather than t since we assume that n will be 30 or more for summary data. The values for average, s, and n can be obtained from descriptive statistics output for a product line for each time period. If the absolute value of Z_N for a product line for a certain characteristic is greater than 3, then this indicates that the process for that product line for the characteristic is not centered on nominal during that time period.

2. Z-Sigma (Z_S):

Z_S is used to show condition of the actual process width of a product line relative to the desired width (i.e., tolerance (T), which is upper specification limit minus lower specification limit).

$$Z_s = \frac{s - s'}{s(s)} \qquad (2)$$

where s is the process standard deviation in a given time period, s' is the desired standard deviation, and s(s) is the standard deviation of s values. If we take sample size of n and if T/8 is the desired standard deviation then Z_S becomes as defined in equation (3)

$$= \frac{\left(s - \left(\frac{T}{8}\right)\right)}{\left(\frac{\left(\frac{T}{8}\right)}{\sqrt{2n}}\right)} \qquad (3)$$

If Z_S is between ∀3, there is no statistical evidence that the specifications are not being met to a satisfactory level. If the Z_S value for a product line for a certain characteristic is less than –3 then the data indicates that the process is capable of satisfying the relevant specification limits during that time period. If Z_S is greater than +3, it means the process in question is too wide to meet the specification limits.

3. Z-Control (Z_C):

Z_C is used to show the condition of the process relative to statistical control. One approach to this issue involves Mean Square Successive Difference (MSSD), which is defined as follows:

$$\mathrm{MSSD} = \frac{1}{n-1}\sum_{i=1}^{n-1}\left(X_{i+1} - X_i\right)^2 \qquad (4)$$

where X_i's are the individual observations and n is the number of observations in a given time period.

Dividing the MSSD by 2, $\frac{\mathrm{MSSD}}{2}$, provides an estimate for potential variance if the process is in control. A comparison of $\frac{\mathrm{MSSD}}{2}$ to the variance calculated the usual way may be used to test for randomness (see Dixon and Massey (1969) and Holmes and Mergen (1995)). If n is greater than 20 and the population is normal then

$$Z_C = \left[1 - \frac{\mathrm{MSSD}}{2s^2}\right] \Big/ \sqrt{\frac{(n-2)}{(n-1)(n+1)}} \qquad (5)$$

is approximately normally distributed with a mean value of zero and a standard deviation of one. If Z_C is greater than +3, it indicates lack of control due to trends; if Z_C is less than −3, it indicates lack of control due to cycles. Z_C values inside ∀3 reflect "random" variation, i.e., no evidence that process is not in control.

Again by comparing Z_C values for different product lines, one can quickly check which product lines are in control (i.e., stable).

3. Example

Suppose the plant that we mentioned in the introduction has two product lines: product A and B. The nominal values and the specification limits for each of the different quality characteristics of these two product lines are given in Table 1 below.

	PRODUCT A			PRODUCT B	
	Chr.1	Chr.2	Chr.3	Chr.1	Chr.2
NOM	50.00	3.00	17.50	30.00	5.00
USL	52.00	5.00	18.50	35.00	7.00
LSL	48.00	1.00	16.50	25.00	3.00

Table 1. Nominal values and specifications for product A and B.

Four monthly averages, standard deviations, and the three Z values for each product line for each characteristic are given in Table 2.

MONTH

	1	2	3	4
PRODUCT A				
Chr.1				
AVE.	50.50	49.60	49.96	49.97
STD.DEV.	0.50	0.48	0.27	0.25
Z_N	7.07	-5.89	-1.05	-0.85
Z_S	0.00	-0.40	-4.60	-5.80
Z_C	1.75	0.10	-2.25	-1.53
Chr.2				
AVE.	3.98	3.50	3.99	4.00
STD.DEV.	0.71	0.45	0.49	0.79
Z_N	9.76	7.85	14.28	8.95
Z_S	4.20	-1.00	-0.20	5.80
Z_C	-0.63	0.30	-0.47	1.01
Chr.3				
AVE.	17.81	17.60	17.64	18.00
STD.DEV.	0.60	0.62	0.59	0.80
Z_N	3.65	1.14	1.68	4.42
Z_S	14.00	14.80	13.60	22.00

Z_C	0.49	-0.65	-0.40	3.43
PRODUCT B				
Chr.1				
AVE.	32.00	31.84	29.99	30.00
STD.DEV.	1.60	1.70	1.45	1.31
Z_N	8.84	3.49	-0.05	0.00
Z_S	2.80	3.60	1.60	0.48
Z_C	0.27	-2.54	1.64	0.99
Chr.2				
AVE.	5.95	4.57	4.97	5.00
STD.DEV.	0.98	0.99	0.69	0.61
Z_N	6.85	-3.07	-0.30	0.00
Z_S	9.60	9.80	3.80	2.20
Z_C	-0.28	-0.24	1.53	-1.59

n = 50 for each month.

Table 2. Averages, Std. dev.'s and 3 Z values for product A and B.

Several different analyses can be done with the Z values given in Table 2. Z_N values in the Table for all three characteristics of product A and two characteristics of product B over the four-month period show how the different characteristics of product A and B are doing with respect to their nominal values. As can be seen from Table 2 above, during the first month characteristics of product A and B all have large positive Z_N values. That means, in both product lines process averages of different characteristics are all very much above their nominal. In the second month, the process average for characteristic 3 of product A is closer to its nominal, but still not centered on the nominal (the average is 1.14 standard deviations of the averages above the nominal). As far as product B is concerned, we see some improvement in bringing the averages for characteristics 1 and 2 closer to their nominal.

Similar analysis could be made for the Z_S and Z_C values of products A and B. For example, Z_S values for characteristic 1 of product A are less than –3 during month three and four, indicating that the process is capable of satisfying the relevant specification limits during this time period. However, Z_S values for characteristic 3 of product A are all greater than +3, implying that the process for this characteristic is not capable of meeting the required specifications.

Z_C values, on the other hand, for characteristics 1 and 2 of product A and characteristics 1 and 2 of product B are all within $\forall 3$, indicating that those processes were in control during this four month period. Characteristic 3 of product A, however, has a Z_C value of 3.43 in the fourth month, which implies that the process for that characteristic is out-of-control in that month.

Another application of these Z values would be charting them over time, like a trend chart, to see the patterns in the process management results.

4. Conclusion

The three Z values presented in this paper are simple tools for management to make quality comparisons of different product lines, characteristics, etc. Some of the advantages, among many, of these Z values can be listed as:

- Uniform scale so different characteristics can be compared easily (weight, length, diameter, temperature, etc.)
- Ease of interpretation of the Z values
- Ability of comparison of the Z values even without charting them
- Ease of making them a part of any SPC system.

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ÖZET

Bu çalışmada idareciye idarenin kalite konusunda ihtiyaç duyduğu noktalarda değişik üretim bantlarındakı kalite performanslarını yapmak için bir metod sunulmuştur. Farklı bantlar, farklı ürünler veya farklı özellikte ayni ürünler üretilebileceyinden ürünlerde kalite karşılaştırmaları genel olarak zordur. Bu makalede önerilen metod makalede tanımlandığı şekilde üç Z değerini kullanmıstır (diger yöntemler için örneğin Holmes (1986) ve Holmes ve Mergen (1988)' e bakınız). Ayrıca bir örnek üzerinde önerilen metod tartışılmıştır.