An Improvement on Target Costing Technique

Hsin-Hung Wu

Graduate Institute of Information Technology and Management
Taichung Healthcare and Management University
No. 500 Lioufeng Road, Wufeng Shiang
Taichung, Taiwan 413, R.O.C.
Phone: (04) 2332-3456 ext. 1942
E-Mail: hhwu@thmu.edu.tw

Abstract

The target costing technique, mathematically discussed by Sauers, only uses the C_p index along with Taguchi loss function and $\overline{X}$-R control charts to setup goal control limits. The new specification limits derived from Taguchi loss function is linked through the C_p value to $\overline{X}$-R control charts to obtain goal control limits. Studies have shown that the point estimator of the C_p index, $\hat{C}_p$, could vary from time to time due to the sampling error. The suggested approach is to use confidence intervals, especially the lower confidence intervals, to replace the point estimator. Therefore, an improvement on target costing technique is presented by applying the lower confidence interval of the $\hat{C}_p$ index and using both Taguchi and Spiring's loss functions together with $\overline{X}$-R charts to make this technique more robust in practice. An example is also provided to illustrate how the improved target costing technique works.

Key Words : Target costing technique, Process capability index, Confidence interval, Loss function, Control charts

1. Introduction

Target costing technique has been widely used by the Japanese companies to determine the price of products [4,8]. By starting with the anticipated acceptable market price, the companies subtract the desired profit margin to obtain a target manufacturing cost. Then, design and manufacturing engineers are responsible to bring the product into being at this cost. By doing so, price can be driven down to the process level, and continuous improvement can be acted by listening to the price concerns of the marketplace.

When the target costing technique is applied, the specification limits can be derived from Taguchi loss function or other types of applicable loss functions. The derived specification limits can be linked through a predetermined capability index value, either obtained from the original data or given by management, along with the conventional control charts to setup goal control limits [8]. Sauers [4] believed that goal control limits form the foundation for directed continuous improvement efforts by considering the price from the marketplace.

In this article, only the "nominal-is-best" loss function is discussed. The formula of the "nominal-is-best" Taguchi loss function is described as follows:

$$L(y)=k(y-T)^2, \qquad (1)$$

where $L(y)$ is the average or expected loss over all customers, k is the quality loss coefficient, and T is the target value. Consider a component with product specification limits $T\pm\Delta$, and the specification limits are 2Δ. Let A_0 be the expected or long run average costs occurred for products made at the specification limit Δ, then k can be determined as

$$k=\frac{A_0}{\Delta^2}. \qquad (2)$$

Equation (3) shows how Equation (1) can be revised by incorporating Equation (2), and Figure 1 shows the relationship.

$$L(y)=\frac{A_0}{\Delta^2}(y-T)^2. \qquad (3)$$

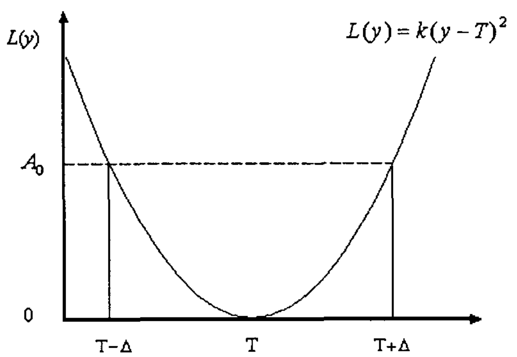

Figure 1. The Nominal-is-Best Taguchi Loss Function

The loss to society is minimized when the products are produced at the target value. On the other hand, the loss increases when the product is away from the target value. In contrast to Taguchi loss function with infinite maximum loss, Spiring [6]has developed the reflected normal loss function to provide a quantifiable maximum loss and magnitude of losses associated with extreme deviations from the target value. The general equation and figure of this reflected normal loss function are depicted in Equation (4) and Figure 2:

$$L(y) = K\{1 - \exp(-\frac{(y-T)^2}{2\gamma^2})\} = K\{1 - \exp(-\frac{8(y-T)^2}{\Delta^2})\}, \quad (4)$$

where y represents the quality measurement, K is the maximum-loss parameter, T is the target value, and γ is a shape parameter, which is defined as $\Delta/4$, where Δ is the distance from the target value to the point where K first occurs. The target value, shape, and maximum-loss parameters allow customization of the loss function to meet practitioners' requirements.

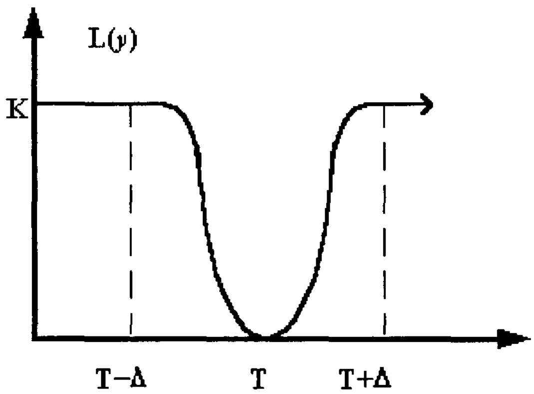

Figure 2. The Reflected Normal Loss Function

The reflected normal loss function is asymptotic to the maximum loss incurred only at $\pm\infty$. The equation of $\gamma = \Delta/4$ ensures that the loss function at the points $T \pm \Delta$ will be 0.9997K, which can be considered to be K. The expected loss associated with the reflected normal loss function defined by Spiring [6] is

$$E(L(y)) = K - K\int \exp(-\frac{(y-T)^2}{2\gamma^2}) f(y)\, dy, \quad (5)$$

where $f(y)$ is the associated probability density function. If the quality characteristic follows a normal distribution with a mean of μ and a standard deviation of σ, the expected loss becomes:

$$EL(y) = K - K\int \frac{1}{\sqrt{2\pi}\sigma}\exp\{-\frac{1}{2}(\frac{(y-T)^2}{\gamma^2}+\frac{(y-\mu)^2}{\sigma^2})\}dy$$

$$= K\{1-\frac{\gamma}{\sqrt{\sigma^2+\gamma^2}}\exp(-\frac{(\mu-T)^2}{2(\sigma^2+\gamma^2)})\}, \quad (6)$$

where the minimum is incurred at $\mu = T$. The applications of the reflected normal loss function in practice can be seen in the reference of Spiring and Yeung [5].

This study only focuses on the use of both Taguchi and Spiring's loss functions with the "nominal-is-best" condition along with the lower confidence interval of the $\hat{C}_p$ index on $\overline{X}$-R charts. Section 2 reviews the commonly used $\overline{X}$-R and $\overline{X}$-S charts and the normality-based process capability indices. The mathematical expressions of the improved target costing technique based upon the "nominal-is-best" Taguchi and Spiring's loss functions, the lower confidence interval of the $\hat{C}_p$ index, and $\overline{X}$-R charts are discussed in Section 3. An example using Taguchi loss function and the lower confidence interval of the $\hat{C}_p$ index on $\overline{X}$-R charts to setup goal control limits is illustrated in Section 4. Finally, conclusions are drawn in Section 5.

2. Control Charts and Process Capability indices

Control charts are typically used (1) to ensure the process is in statistical control, (2) to provide alarm when the process shows out-of-control signals, and (3) to provide the prerequisite information for process capability analysis [4]. The most commonly seen control charts are $\overline{X}$-R and $\overline{X}$-S. For $\overline{X}$-R charts, the formulas are

$$\text{UCL}(R) = D_4\,\overline{R}, \quad (7)$$

$$\text{CL}(R) = \overline{R}, \quad (8)$$

$$\text{LCL}(R) = D_3\,\overline{R}, \quad (9)$$

$$\text{UCL}(\overline{X}) = \overline{\overline{X}} + 3\frac{\hat{\sigma}}{\sqrt{n}} = \overline{\overline{X}} + 3\frac{\overline{R}}{d_2\sqrt{n}} = \overline{\overline{X}} + A_2\overline{R}, \quad (10)$$

$$CL(\overline{X}) = \overline{\overline{X}}, \quad (11)$$

and

$$LCL(\overline{X}) = \overline{\overline{X}} - 3\frac{\hat{\sigma}}{\sqrt{n}} = \overline{\overline{X}} - 3\frac{\overline{R}}{d_2\sqrt{n}} = \overline{\overline{X}} - A_2\overline{R}, \quad (12)$$

where UCL, CL, and LCL stand for upper control limit, center line, and lower control limit, respectively, $\hat{\sigma} = \overline{R}/d_2$, n is the sample size of the subgroup, and d_2, D_4, D_3, and A_2 are constant [1]. For $\overline{X}$ and S charts, the formulas are

$$UCL(S) = B_4\ \overline{S}, \quad (13)$$

$$CL(S) = \overline{S}, \quad (14)$$

$$LCL(S) = B_3\ \overline{S}, \quad (15)$$

$$UCL(\overline{X}) = \overline{\overline{X}} + 3\frac{\hat{\sigma}}{\sqrt{n}} = \overline{\overline{X}} + 3\frac{\overline{S}}{c_4\sqrt{n}} = \overline{\overline{X}} + A_3\overline{S}, \quad (16)$$

$$CL(\overline{X}) = \overline{\overline{X}}, \quad (17)$$

and

$$LCL(\overline{X}) = \overline{\overline{X}} - 3\frac{\hat{\sigma}}{\sqrt{n}} = \overline{\overline{X}} - 3\frac{\overline{S}}{c_4\sqrt{n}} = \overline{\overline{X}} - A_3\overline{S}, \quad (18)$$

where $\hat{\sigma} = \overline{S}/c_4$ and c_4, B_4, B_3, and A_3 are constant [1].

After the process is in statistical control, process capability analysis can be applied to determine if the process is capable to produce high quality products. Typically, C_p and C_{pk} are the well-known process capability indices and widely used throughout industry to quantify the ability of a process within specification limits when the data are normally distributed. The formulas of the normality-based C_p and C_{pk} indices are

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{\Delta}{3\sigma}, \quad (19)$$

and

$$C_{pk} = \min(C_{pu}, C_{pl}) = \min(\frac{USL-\mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}) \tag{20}$$
$$= \min(\frac{(T+\Delta)-\mu}{3\sigma}, \frac{\mu-(T-\Delta)}{3\sigma})$$

where *USL*, *T*, and *LSL* are the upper specification limit, target value, and lower specification limit, respectively, and 2Δ is the distance between *USL* and *LSL*. In Equations (19) and (20), $\mu$is the mean which is the sum of the numerical values of the measurement divided by the number of items examined, and σ is the standard deviation which is the square root of the average squared deviates from the mean.

Typically, μ and σ are usually unknown, and estimations from the sample data are required. If control charts are implemented prior to processcapability analysis, Equations (19) and (20) can be revised as follows:

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}} = \frac{\Delta}{3\hat{\sigma}}, \tag{21}$$

and

$$\hat{C}_{pk} = \min(\hat{C}_{pu}, \hat{C}_{pl}) = \min(\frac{USL - \bar{\bar{X}}}{3\hat{\sigma}}, \frac{\bar{\bar{X}} - LSL}{3\hat{\sigma}}) \tag{22}$$
$$= \min(\frac{(T+\Delta)-\bar{\bar{X}}}{3\hat{\sigma}}, \frac{\bar{\bar{X}}-(T-\Delta)}{3\hat{\sigma}}),$$

where $\bar{\bar{X}}$ is computed from $\bar{X}$ chart. For $\bar{X}$-R charts, $\hat{\sigma}$ is replaced by $\bar{R}/d_2$, while $\hat{\sigma}$ is substituted by $\bar{S}/c_4$ for $\bar{X}$-S charts [3]. The third approach is to use sample standard deviation, $S = \sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 / n-1}$, and $\bar{X}$ from the overall samples to replace $\hat{\sigma}$ and $\bar{\bar{X}}$, respectively, in Equations (21) and (22).

The point estimators, such as $\hat{C}_p$ and $\hat{C}_{pk}$, could mislead the assessment of process performance due to the sampling error [3]. As a result, using confidence intervals might be the simplest and have the advantage without making prior judgments about the process capability [3]. It is worth to note that using $\bar{R}/d_2$ (based upon the range) to estimate $\hat{\sigma}$ is more appropriate if $\bar{X}$-R charts ensure the process is in statistical control. The study of Li, Owen, and Borrego [2] provides both mathematical method and numerical figures to construct the lower confidence interval for the $\hat{C}_p$ index based on the range. That is, a $100\alpha\%$ lower confidence limit, $c_0 = C_p / \hat{C}_p$, on C_p satisfies

$$P_r(C_p \geq c_0) = P_r\left(\frac{C_p}{\hat{C}_p} \geq \frac{c_0}{\hat{C}_p}\right) = P_r\left(\frac{\overline{R}}{d_2\sigma} \geq \frac{c_0}{\hat{C}_p}\right) = \alpha, \tag{23}$$

and

$$P_r\left(\frac{\overline{R}}{d_2\sigma} \leq \frac{c_0}{\hat{C}_p}\right) = P_r\left(\frac{\overline{R}}{\sigma} \leq \frac{d_2 c_0}{\hat{C}_p}\right) = P_r\left(\frac{\overline{R}\sqrt{v}}{c\sigma} \leq \frac{\sqrt{v} d_2 c_0}{c\hat{C}_p}\right) \tag{24}$$

$$\approx P_r\left(\chi_v \leq \frac{\sqrt{v} d_2 c_0}{c\hat{C}_p}\right) = 1 - \alpha$$

So, $\sqrt{v} d_2 c_0 / c\hat{C}_p = \chi_{v,1-\alpha}$, or the ratio of $c_0 / \hat{C}_p = \sqrt{\chi^2_{v,1-\alpha}}\left(c/\sqrt{v} d_2\right)$, where $\chi^2_{v,1-\alpha}$ is the upper -th percentile of the chi-square distribution with v degrees of freedom. The following Table 1 provides some c_0 values for the lower 95 percent confidence limit from Li, Owen, and Borrego [2].

Table 1. The c_0 Values for the Lower 95 Percent Confidence Limit

Subgroup Sample Size	Number of Subgroups		
	10	20	30
4	0.783	0.845	0.873
5	0.811	0.865	0.890
6	0.829	0.879	0.901

3. The Improvement on Target costing Technique

If a quality improvement program is implemented, and the average loss of $L(y)$ using Taguchi loss function is expected to be $hL(y) = L'(y) = k\Delta'^2$, where $0 < h < 1$, then Δ' is

$$\Delta' = \sqrt{\frac{L'(y)}{k}} = \Delta\sqrt{\frac{L'(y)}{A_0}} = \Delta\sqrt{\frac{hL(y)}{A_0}}, \qquad (25)$$

where $k = A_0/\Delta^2$ from Equation (2). If the management decides that the quality level cannot be lower than the C_p value, the $\hat{C}_p$ value estimated from the sample data should be at least C_p/c_0. In fact, the C_p value can be viewed as the lower confidence interval of the $\hat{C}_p$ value. When the C_p value is determined and $2\Delta'$ are computed from Equation (25), then the relationship is as follows:

$$C_p = c_0\hat{C}_p = \frac{2\Delta' c_0}{6\hat{\sigma}'} = \frac{\Delta' c_0}{3\hat{\sigma}'}, \qquad (26)$$

where $\hat{\sigma}'$ is the new standard deviation to achieve the $\hat{C}_p$ value. Furthermore, $\hat{\sigma}'$ can be expressed as follows by applying Equations (25) and (26):

$$\hat{\sigma}' = \frac{\Delta' c_0}{3C_p} = \frac{\Delta'}{3\hat{C}_p} = \frac{\Delta}{3\hat{C}_p}\sqrt{\frac{L'(y)}{A_0}} = \frac{\Delta}{3\hat{C}_p}\sqrt{\frac{hL(y)}{A_0}} \geq 0. \qquad (27)$$

When $\hat{\sigma}'$ is known from Equation (27) and can be replaced by $\overline{R}'/d_2$, the goal control limits for $\overline{X}$ -R charts are

$$\overline{\overline{X}} \pm 3\frac{\hat{\sigma}'}{\sqrt{n}} = \overline{\overline{X}} \pm 3\frac{1}{\sqrt{n}}\frac{\Delta}{3\hat{C}_p}\sqrt{\frac{hL(y)}{A_0}} = \overline{\overline{X}} \pm \frac{\Delta}{\hat{C}_p}\sqrt{\frac{hL(y)}{nA_0}}, \qquad (28)$$

$$\text{UCL}(R) = D_4\overline{R}' = D_4 d_2\hat{\sigma}' = D_4 d_2\frac{\Delta}{3\hat{C}_p}\sqrt{\frac{hL(y)}{A_0}}, \qquad (29)$$

and

$$\text{LCL}(R) = D_3\overline{R}' = D_3 d_2\hat{\sigma}' = D_3 d_2\frac{\Delta}{3\hat{C}_p}\sqrt{\frac{hL(y)}{A_0}}, \qquad (30)$$

When Spiring's loss function is considered, the mathematical relationship is as follows: Suppose a quality improvement program is implemented, the general loss is to be reduced to $L_1(y)=hK$, where $0 < h < 1$. If the loss function $L_1(y)$ applying Equation (4) is defined in the interval [T-Δ', T +Δ'], at the point y at which $8(y-T)^2 = \Delta'$, then $L_1(y)$ becomes

$$L_1(y) = hK = K\{1-\exp(-\frac{8\Delta'}{\Delta^2})\} \qquad (31)$$

and

$$\Delta' = \sqrt{\frac{-\Delta^2}{8}\ln(1-h)}. \qquad (32)$$

If the management decides that quality level cannot be lower than the C_p value, the $\hat{C}_p$ value should be at least C_p/c_0. When the C_p value is determined and $2\Delta'$ are computed from Equation (32), the relationship is

$$C_p = c_0 \hat{C}_p = \frac{2\Delta' c_0}{6\hat{\sigma}'} = \frac{\Delta' c_0}{3\hat{\sigma}'}, \qquad (33)$$

where $\hat{\sigma}'$ can be further expressed as below by incorporating Equations (32) and (33).

$$\hat{\sigma}' = \frac{\Delta' c_0}{3C_p} = \frac{\Delta'}{3\hat{C}_p} = \frac{1}{3\hat{C}_p}\sqrt{\frac{-\Delta^2}{8}\ln(1-h)} = \frac{\Delta}{6\hat{C}_p}\sqrt{\frac{\ln(1-h)}{2}} \geq 0. \qquad (34)$$

When $\hat{\sigma}'$ is known from Equation (34), the goal control limits for $\overline{X}$-R charts are

$$\overline{\overline{X}} \pm 3\frac{\hat{\sigma}'}{\sqrt{n}} = \overline{\overline{X}} \pm 3\frac{1}{\sqrt{n}}\frac{1}{3\hat{C}_p}\sqrt{\frac{-\Delta^2}{8}\ln(1-h)} = \overline{\overline{X}} \pm \frac{\Delta}{\hat{C}_p}\sqrt{\frac{-\ln(1-h)}{8n}}, \qquad (35)$$

$$\text{UCL}(R) = D_4\overline{R}' = D_4 d_2 \hat{\sigma}' = D_4 d_2 \frac{1}{3\hat{C}_p}\sqrt{\frac{-\Delta^2}{8}\ln(1-h)}, \qquad (36)$$

and

$$\text{LCL}(R) = D_3\overline{R}' = D_3 d_2 \hat{\sigma}' = D_3 d_2 \frac{1}{3\hat{C}_p}\sqrt{\frac{-\Delta^2}{8}\ln(1-h)}, \qquad (37)$$

4. An Example

To demonstrate the improved target costing technique, the data from Wu [8] are used and shownin Table 2. The values of *USL*, *T*, and *LSL* are 50, 37, and 24, respectively.

Table 2. The Data from Wu [8]

Subgroup	Sample Size for Each Subgroup ($n = 5$)					Average ($\overline{X}$)	Range (R)
1	36	35	34	33	32	34.0	4
2	31	31	34	32	30	31.6	4
3	30	30	32	30	32	30.8	2
4	32	33	33	32	35	33.0	3
5	32	34	37	37	35	35.0	5
6	32	32	31	33	33	32.2	2
7	33	33	36	32	31	33.0	5
8	29	33	34	33	34	32.6	5
9	36	36	35	31	31	33.8	5
10	32	32	32	34	34	32.8	2
11	34	38	35	34	38	35.8	4
12	32	34	36	35	36	34.6	4
13	36	37	34	30	33	34.0	7
14	36	35	37	34	33	35.0	4
15	30	37	33	34	35	33.8	7
16	28	31	33	33	33	31.6	5
17	33	30	34	33	35	33.0	5
18	30	31	33	31	35	32.0	5
19	35	36	29	27	32	31.8	9
20	33	35	35	39	36	35.6	6
Total						666.0	93
Average						33.30	4.65

Assume the data are in statistical control and normally distributed. The UCL, CL, and LCL of $\overline{X}$ chart using Equations (10)-(12) are 35.98, 33.30, and 30.62, respectively, while 9.83, 4.65, and 0 are the values for UCL, CL, and LCL of R chart using Equations (7)-(9), where $\hat{\sigma} = \overline{R}/d_2 = 1.999$, $d_2=$

2.326, $A_2 = 0.577$, $D_4 = 2.115$, and $D_3 = 0$ for $n = 5$. The $\hat{C}_p$ and $\hat{C}_{pk}$ values using Equations (21) and (22) are 2.17 and 1.55. The actual product quality using the 95 percent confidence is not going to be lower than $C_p = c_0 \hat{C}_p = (0.865)(2.17) = 1.88$, where $c_0 = 0.865$, with $n = 5$ and the subgroup of 20.

Suppose the target costing technique is applied, the expected or long run average cost from the product (A_0) is \$500, and Δ is 13. The quality loss coefficient k is $A_0/\Delta^2 = 500/13^2 = 2.96$. If the company decides to reduce the cost by 10% and $C_p$is to be improved and set to 2.00 (the original $C_p$is only 1.88), the new specification limit Δ' can be solved by $L'(y) = 0.9(500) = 450 = 2.96\Delta'^2$, where Δ' equals 12.33. When $C_p$is set to 2.00, the point estimator $\hat{C}_p$ using Equation (26) should not be lower than $\hat{C}_p = C_p/c_0 = 2.00/0.865 = 2.31$. The $\hat{\sigma}'$ value can be calculated as follows by Equation (27):

$$\hat{\sigma}' = \frac{\Delta'}{3\hat{C}_p} = \frac{12.33}{3(2.31)} = 1.779.$$

The goal control limits for $\overline{X}$-R charts using Equations (28)-(30) are

$$\text{UCL}(\overline{X}) = \overline{\overline{X}} + 3\frac{\hat{\sigma}'}{\sqrt{n}} = 33.30 + 3\frac{1.779}{\sqrt{5}} = 35.69,$$

$$\text{CL}(\overline{X}) = \overline{\overline{X}} = 33.30,$$

$$\text{LCL}(\overline{X}) = \overline{\overline{X}} - 3\frac{\hat{\sigma}'}{\sqrt{n}} = 33.30 - 3\frac{1.779}{\sqrt{5}} = 30.91,$$

$$\text{UCL}(R) = D_4\overline{R}' = D_4 d_2 \hat{\sigma}' = (2.115)(2.326)(1.779) = 8.75,$$

$$\text{CL}(R) = \overline{R}' = d_2 \hat{\sigma}' = (2.326)(1.779) = 4.14,$$

and

$$\text{LCL}(R) = D_3\overline{R}' = D_3 d_2 \hat{\sigma}' = (0)(2.326)(1.779) = 0.$$

If the improved target costing technique is applied by reducing the 10% cost and setting the C_p value at 2.00, i.e., $\hat{C}_p = 2.31$ with the possible sampling error, the variation should be reduced. As a result, tighter goal control limits can be expected compared with the traditional $\overline{X}$-R control limits, summarized in Table 3. When goal control limits are applied to $\overline{X}$-R charts directly, all of the average ($\overline{X}$) and range (R) values should be within the goal control limits. Obviously, the average value of subgroup 11 is above UCL($\overline{X}$), and the average value of subgroup 3 is below LCL($\overline{X}$), whereas the average range value of subgroup 19 is above UCL(R). Therefore, a corrective action should be conducted.

Table 3. The Comparison between Traditional and Goal Control Limits

	Traditional Control Limits	Goal Control Limits
UCL($\overline{X}$)	35.98	35.69
CL($\overline{X}$)	33.30	33.30
LCL($\overline{X}$)	30.62	30.91
UCL(R)	9.83	8.75
CL(R)	4.65	4.14
LCL(R)	0	0

In this example, the target costing technique is applied to both reduce the cost and improve the process performance at the same time. It can also be utilized by either reducing the cost or improving the product quality. For instance, if $C_p$is set to 2.50 by management when the other situations are fixed, the new goal control limits for $\overline{X}$-R charts are presented as follows:

$$\hat{\sigma}' = \frac{\Delta' c_0}{3C_p} = \frac{12.33(0.865)}{3(2.50)} = 1.422,$$

$$\text{UCL}(\overline{X}) = \overline{\overline{X}} + 3\frac{\hat{\sigma}'}{\sqrt{n}} = 33.30 + 3\frac{1.422}{\sqrt{5}} = 35.21,$$

$$\text{CL}(\overline{X}) = \overline{\overline{X}} = 33.30,$$

$$\text{LCL}(\overline{X}) = \overline{\overline{X}} - 3\frac{\hat{\sigma}'}{\sqrt{n}} = 33.30 - 3\frac{1.422}{\sqrt{5}} = 31.39,$$

$\mathrm{UCL}(R) = D_4\overline{R}' = D_4 d_2 \hat{\sigma}' = (2.115)(2.326)(1.422) = 7.00,$

$\mathrm{CL}(R) = \overline{R}' = d_2 \hat{\sigma}' = (2.326)(1.422) = 3.31,$

and

$\mathrm{LCL}(R) = D_3\overline{R}' = D_3 d_2 \hat{\sigma}' = (0)(2.326)(1.442) = 0.$

To ensure all of the $\overline{X}$-R values are within the limits, product variation should be further reduced, i.e., the improvement of product quality. On the other hand, the reflected normal loss function can be applied by the similar procedure discussed above. As long as the $\hat{\sigma}'$ value can be calculated by Equation (34), the goal control limits, thus, can be established.

5. Conclusions

This article provides an improved target costing technique by considering the lower confidence interval of the $\hat{C}_p$ index which reduces the sampling error. The new specification limits derived from either Taguchi or Spiring's loss function is linked through the lower confidence interval of the $\hat{C}_p$ value to $\overline{X}$-R charts to obtain goal control limits. The philosophy of the target costing technique is to relentlessly improve product quality and reduce costs such that a more robust product would be more competitive in the marketplace. Obviously, with the consideration of the lower confidence interval of the $\hat{C}_p$ value along with Taguchi and Spiring's loss functions, this technique can be applied more effectively.

References

1. Gitlow, H., Oppenheim, A., and R. Oppenheim, *Quality Management: Tools and Methods for Improvement: Second Edition*, RichardD. Irwin (1995).
2. Li, H., Owen, D.B., and S.A. Borrego A, "Lower Confidence Limits on Process Capability Indices based on the Range," *Communications in Statistics Simulation and Computation*, 19(1), 1-24 (1990).

3. Porter, L.J. and J.S. Oakland, "Process Capability Indices An Overview of Theory and Practice," *Quality and Reliability Engineering International*, 7, 437-448 (1991).
4. Sauers, D.G., "Using the Taguchi Loss Function to Reduce Common-Cause Variation," *Quality Engineering*, 12(2), 245-252 (1999-2000).
5. Spiring, F.A. and A.S. Yeung, "A General Class of Loss Function with Industrial Applications," *Journal of Quality Technology*, 30(2), 152-162 (1998).
6. Spiring, F.A., "The Reflected Normal Loss Function," *The Canadian Journal of Statistics*, 21(3), 321-330 (1993).
7. Taguchi, G., *Introduction to Quality Engineering: Designing Quality into Products and Processes*, Kraus, White Plains, New York (1986).
8. Wu, H.-H., "Quality Management: A Target Costing Approach," *Journal of the Chinese Institute of Industrial Engineers*, 20(1), 13-20 (2003).